BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF METROPOLITAN DISTRICT COMMISSION BEACHES MASSACHUSETTS

PART B

REVERE BEACH

JUNE 1, 1949

CORPS OF ENGINEERS, U. S. ARMY

OFFICE OF THE DIVISION ENGINEER

NEW ENGLAND DIVISION, BOSTON, MASSACHUSETTS

REVERE BEACH

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*Apply also to Part A - Lynn-Nahant Beach

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NOT FOR PUBLIC RELEASE

BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF METROPOLITAN DISTRICT COMMISSION BEACHES, BOSTON, MASSACHUSETTS

INTRODUCTORY

The cooperative study of Metropolitan District Commission Beaches in Metropolitan Boston, Massachusetts, comprises studies of five beaches, one of which (Winthrop Beach) has previously been reported on to Congress. These beaches are essentially independent of each other, in so far as the scope of the study is concerned. The cooperating agency stated its objective in the prosecution of the study to be the determination of the best method of preventing further erosion, stabilizing, and improving the beaches, and protecting the sea-walls. Report on studies of Winthrop Beach was made by the Beach Erosion Board and submitted to Congress December 9, 1948. Report on the remaining beaches is made in four parts, as follows:

A. Lynn-Nahant Beach
B. Revere Beach
C. Quincy Shore Beach
D. Nantasket Beach

SYLLABUS - REVERE BEACH

The Division Engineer finds that, between Northern Circle and a point near Shirley Avenue, Revere Beach has eroded; stones deposited on backshore areas otherwise suitable for recreational use create conditions which now prejudice such use, and that partially damaged shore protective structures, though endangered by the eroding beach, protect adjacent land areas. He also finds that the formation of the stone ridge between a point near Shirley Avenue and Eliot Circle cannot be prevented. The Division Engineer recommends as the best method of improving Revere Beach, preventing further erosion and protecting shore line structures, and adjacent highway and property between Northern Circle and a point near Shirley Avenue, a distance of about 13,700 feet, the raising of the backshore generally to elevation 18.0 feet above mean low water, with sand fill at an estimated cost of $1,012,000. He also recommends that the stone ridge between the point near Shirley Avenue and Eliot Circle shall not be disturbed.

The Division Engineer recommends that the Commonwealth of Massachusetts adopt a project for placing the recommended sand fill between Northern Circle and the point near Shirley Avenue and that the United States participate in the project by contributing funds in an amount equal to one-third of the cost of construction of new work, estimated to be $337,300, subject to the conditions specified in the report. During the course of the study, the Massachusetts General Court authorized the cooperating agency to construct protective structures in the Point of Pines area, outside the study scope. With data obtained on the study of Revere Beach, the Division Engineer found the principal problem in the area to be the flooding of roads and private property by extreme high waters. The construction of a concrete encased steel sheet pile sea-wall between General Edwards Bridge and Northern Circle is recommended as the best

method of protecting this area. The adoption of a Federal Project is not recommended without further study of this area.

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CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON, MASS.

June 1, 1949

SUBJECT: Beach Erosion Control Report on Cooperative Study of Metropolitan District Commission Beaches, Boston, Massachusetts: Part B - Revere Beach.

TO: The Chief of Engineers
Department of the Army
Washington 25, D. C.

I. GENERAL

1. Authority. - A formal application from the Metropolitan District Commission of the Commonwealth of Massachusetts, dated August 9, 1945, for a cooperative study of beach problems within the Metropolitan District in the vicinity of Boston, Massachusetts, including Lynn-Nahant Beach, Revere Beach, Winthrop Beach, Quincy Shore, and Nantasket Beach, and providing for prosecution jointly by the Metropolitan District Commission and the United States was approved by the Chief of Engineers, United States Army, October 2, 1945, in accordance with the authority conferred by the provisions of Section 2 of the River and Harbor Act approved July 3, 1930, and Public Law 166, 79th Congress, approved July 31, 1945.

2. At the request of the Metropolitan District Commission, the study of Winthrop Beach was given priority over the study of other beaches to allow a separate report to be made on Winthrop prior to completion of the entire study. A report on "Beach Erosion Control Study, Winthrop Beach, Mass." was made by the Beach Erosion Board and submitted to Congress December 9, 1948, and is published in House Document No. 764, 80th Congress, 2nd Session.

3. Purpose. - The purpose of the investigation of the general study of Metropolitan District Beaches is to determine the best method of preventing further erosion, stabilizing and improving beaches, and protecting the seawalls.

4. Prosecution of the Study. - The Commonwealth of Massachusetts, through the Metropolitan District Commission, contributed one-half the cost of the study. The field work and collection of basic data for the study were carried out by the District Engineer, Boston, Massachusetts, with the exception of economic data, which were collected by the cooperating agency. A geological study of the area, except the mainland section of the Lynn-Nahant Beach, was prepared by the United States Department of the Interior, Geological Survey, under a cooperative geological project of the Massachusetts Department of Public Works. The report on Winthrop Beach was prepared by the Beach Erosion Board. The report on other beaches included in the study has been prepared by the Division Engineer, New England Division.

5. Preparation of Reports. - The five beaches comprising the study, in so far as their physical location and the scope of the study are concerned, are independent shore units which may properly be treated as separate beaches. A separate report has been prepared on Winthrop Beach. The report on the remaining beaches has been divided into four parts, as follows:

Part A - Lynn-Nahant Beach
Part B - Revere Beach
Part C - Quincy Shore Beach
Part D - Nantasket Beach

Each of the four parts is issued as a complete report for the subject beach, and contains general paragraphs numbered 1 to 5, inclusive, and Plates 1 and 2, which are common to all four parts. Part B also contains Plates A-2 to A-5, inclusive, which are common to both Parts A and B.

II. DESCRIPTION

6. Location. - Revere Beach is located in the City of Revere, Essex County, Massachusetts, approximately 7 miles north of the main entrance channel to Boston Harbor and 5-1/2 miles northeast of the City of Boston. (See Plate I, U. S. Coast and Geodetic Survey Chart 1207 and U. S. Geological Survey Boston Bay Quadrangle).

7. General Description. - Revere Beach is a barrier beach separating the Lynn marshes from Broad Sound. The beach extends a distance of approximately 3-1/2 miles northward from Roughan's Point to the mouth of Saugus River. The southern half of the beach is developed as an extensive amusement area. The northern half of the beach is developed as a middle class residential district, with the greatest population being concentrated in the Point of Pines area. Roughan's Point is a cuspate tombolo which tied the formerly existing Cherry Island to the mainland, and has been developed as a summer and year-round residential area. Cherry Island has been reduced to a bar.

8. The present Revere Beach is the result of the erosion of glacial and river deposits and the redistribution of such materials through beach-building forces. The position of the beach is stabilized by Roughan's Point and Cherry Island Bar, Oak Island, and the Saugus River. The shore is of hard-packed sand with varying deposits of stones occurring on back shore areas. In most places it is from 250 to 600 feet wide, but widens to more than 1000 feet at its northern end.

9. The shore line of Revere Beach consists of the Metropolitan District Commission Revere Beach Reservation which extends approximately 3 miles northeast of Roughan's Point, and Point of Pines which extends approximately 1/2 mile from the Reservation to the Saugus River. The

Reservation comprises a wide boulevard, including both sidewalks, a series of sea-walls, pavilions and retaining walls along the seaward edge of the boulevard, and the beach. A large pleasure park development, containing all types of rides, games, amusement devices and refreshment stands, borders the southerly 6000 feet of the Reservation. Private residences interspersed with refreshment stands and restaurants border the balance of the Reservation. The area north of the Reservation, designated as Point of Pines, is a densely populated, permanent residential area bounded by a paved town road paralleling a beach which is wide on the ocean side and narrow on the river side. The road is partially protected by miscellaneous walls, bulkheads and riprap placements. The area south of the Reservation designated as Roughan's Point is a summer and year round residential area protected by a sea-wall and riprap shore protection owned by the Massachusetts Department of Public Works. The beach is narrow and stony.

10. Revere Beach is exposed to direct action from the open ocean through the southeast quadrant. Protection from storms from this quadrant is partially afforded by Cherry Island Breakwater. The beach is afforded protection from direct attack from the northeast by Big and Little Nahant and the tombolos connecting them to the mainland. Storms originating in the northeast quadrant attack the beach through the refraction of the storm waves around Nahant.

11. Revere Beach is connected to other parts of the City of Revere and to all sections of Metropolitan Boston by excellent trunk highways. A principal state highway route parallels the beach about 1000 feet inland. The amusement area of the beach is served directly by the Metropolitan Transit Authority system, being reached by a ten cent fare from all parts of Boston. Free public parking areas are provided for automobiles along most sections of the Metropolitan District Commission Reservation. The beach is open to full and free use by the public. A large bath house with a capacity of 4500

bathers is operated at the beach by the Commission, the charge for accommodations being twenty-five cents. The daily attendance at Revere Beach is 150,000 to 200,000 people, with Sunday and holiday attendance increasing to 400,000 to 500,000 people. The location and accessibility of the area; the original long, wide sandy beach; the development of the State-operated Reservation; and the development of the amusement park has made Revere Beach the most popular and most used beach in Massachusetts.

12. Landward of Revere Beach Drive is a narrow strip of land forming a barrier between the sea and marshes. This land is generally of glacial deposit, with some areas of artificial fill, and is less than one-half mile wide. It is traversed by several roads, including a principal state highway and a railroad. Adjacent to the amusement area there are a number of buildings utilized as roller skating rinks, bowling alleys, cafes and similar enterprises associated with such areas. The balance of the land is generally utilized as a moderate priced year-round residential area.

III. GEOLOGY

13. Classification of Beach. - Revere Beach is a barrier beach separating the Lynn tidal marshes from the ocean.

14. Bed Rock. - There is no exposed bed rock in the vicinity of Revere Beach. Borings in the area indicate that bed rock is more than 20 feet below mean low water. Bed rock therefore does not affect shore line processes in the area.

15. Surficial Deposits. - a. Till. - Glacial till is found at Young's Hill, west of Crescent Beach (amusement area), at Beachmont south of Roughan's Point, and beneath Cherry Island Bar. The till rests on bed rock. Some of the beach material in the area immediately west and north of Roughan's Point was derived from the erosion of this till, and some of the material on other parts of the beach may have been derived from other areas of till. This till contains clay, silt, and sand, as well as larger fragments; however, none of the clay and little of the silt were used in the formation of Revere Beach. Erosion of till may be furnishing a small amount of material to Revere Beach at the present time.

b. Outwash Sands and Gravels. - Outwash sands and gravels crop out at Oak Island, in the area between Young's Hill and Crescent Beach, and along Revere Street, which terminates at the beach at the north end of the amusement area. They may also be present offshore from these areas, and the tops of these deposits may not be far from mean low water. The outwash sands and gravels rest on till and are an excellent source of beach material. Erosion of these and other similar deposits may have furnished and may still be furnishing material for Revere Beach.

c. Clay. - Borings indicate that blue clay, which may rest on till, outwash, or bed rock, underlies much of Revere Beach. Though composed predominately of clay, it contains a small fraction of material larger than

the silt sizes, and some of this coarser material was used in the construction of Revere Beach. Since the surface of the clay in the Revere Beach area is usually below the low water mark, it is not an important source of beach material.

d. Sand and Silt. - Following the deposition of the clay, the sea level dropped to a point scores of feet below its present stand, so that the shore line was several miles eastward. During this period, sand and silt were deposited on the clay by streams running across it. Some of this material was also used in the construction of Revere Beach, although it was probably not an important source.

e. Marshland. - Marshland underlaid by peat occupies most of the area in back of Revere Beach. The peat rests directly on blue clay, and therefore is younger than the clay. Although some of the peat is younger than the present Revere Beach, most of it is older. There is no evidence that peat crops out on the beach face, so that the peat has played no part either in the present beach regime or in the evolution of Revere Beach.

f. Summary. - Bed rock and peat supplied little or no material to Revere Beach. Till, outwash and clay, were all sources of beach material, although their relative importance is not known.

16. Geologic History. - After the consecutive deposition of the till, outwash and clay, upon bed rock, the sea level dropped from a position somewhat higher than that at present to one scores of feet lower. During this low stand of the sea, the Saugus and other rivers ran across the clay, and in places silt, sand and gravel, were deposited. Beaches were formed close to the shore line by material derived from various sources. As sea level rose, the beaches moved landward. The first beach to occupy an area close

to the present Revere Beach, probably terminated approximately four thousand feet south of the tip of Point of Pines. Following this, the beach grew northward. Lynn Beach was probably in existence at this time, and its presence decreased the effectiveness of the northeast storms, and made it easier for Revere Beach to grow northward. The growth of Revere Beach in this direction may well have become progressively slower, however, because of the action of the currents in Saugus River.

17. The greater width of the northern end of Revere Beach is due to a number of factors. A succession of hooks grew northward and westward. Their orientation suggests that the beach south of the first-formed hooks has retrograded, and this in turn caused the northern end of the beach to prograde southeastward. The area between the hooks has been filled in by marsh and artificially placed land deposits. The narrowness of the beach south of Point of Pines, indicates that only a limited amount of beach material has been supplied from the various sources.

18. Geologically, Revere Beach is in a general way stablized by: (1) Beachmont and Cherry Island Bar; (2) deposits east of Oak Island, Young's Hill, and Revere Street; (3) current action in the Saugus River; (4) the protective influence of Lynn Beach and Nahant; (5) shallow water in Broad Sound. The general configuration of the beach, an analysis of exposure and fetch, and a consideration of possible sources of beach material, suggest that the southern part of Revere Beach may be retrograding, and that the northern may be in equilibrium or even prograding.

19. If the beach continued to retrograde in the vicinity of Oak Island, Revere Beach, and Young's Hill, greater quantities of beach material would be supplied to the beach because of the erosion of larger areas of outwash. This would tend to stabilize the beach in this area, and might even prograde it farther north. This retrograding is not a factor in the present problem, as protective structures prevent its occurrence above tidal ranges

and scores of years will pass before such action can be affected.

IV. FACTORS AFFECTING SHORE PROCESSES

20. Composition of Beach. - (Figures B-1 to B-3 inclusive) The shore of Roughan's Point is stony and boulder-strewn. The present Revere Beach is a sandy beach with variable deposits of stone occurring in backshore areas. The foreshore is hard-packed sand having a very flat profile. At the southerly end of the beach the backshore area is normally covered by a large stone beach ridge which extends from Profile 17 to Profile 13. This ridge has been artificially removed two times, the last being in the spring of 1946 when all stone above the underlaying beach sand was removed between Profiles 16 and 13. The stone deposits continue northerly from the ridge along the beach, being very dense in front of the amusement area between Profiles 13 and 4, where they tend to bury backshore areas and shore protection structures. Northerly of Profile 4 the stone deposits vary in density from moderate deposits to traces. In the Point of Pines area the stone deposits generally die out and a large sand dune has developed at the mouth of the Saugus River. Sand in backshore area is generally soft and loosely packed. Stone deposits, outside of the ridge area, form as beach cusps and are greater in the winter months than they are in the summer months. A complete description of shore conditions is contained in Appendix II.

21. A generalized columnar section of Revere Beach indicates its composition to be beach sands and gravels overlaying strata of peat, blue clay, outwash sands and gravels, glacial till (hard-pan) and bed rock which is generally over 20 feet below the surface. Borings showing the specific beach composition are available for the extreme northerly and southerly ends of the study area.

22. Borings taken in 1909 to a depth of 35 - 38 feet near the mouth of the Saugus River, indicate the area is composed of beach and

harbor sands which overlay clay. West of the highway bridges at a depth of 10 feet below mean low water, the sand stratumwas 3 feet thick. Nearer the mouth of the river, where the Point of Pines emerged above river level, the sand was 35 feet deep at the mean low water line. Offshore in Lynn Harbor at a depth of 8 feet below mean low water, the sand was 6 feet thick.

23. Borings taken along the line of the Eliot Circle Sea-wall prior to its construction in 1910, generally ranged in depth from mean low water to 4 feet below mean low water. The materials comprised 6 to 10 feet of sand and gravel overlying 2 to 5 feet of mud and decayed vegetation which in turn overlaid hard-pan and gravel. The upper stratum of material in two borings contained no gravel and was soft, fine sand, and in one other boring the gravel contained rocks.

24. Borings taken along the line of the Roughan's Point Sea-wall prior to its construction in 1936 extended from 14 to 36 feet below mean low water, and near the outer end of the point terminated on the north face of the point, adjacent to the end of the wall. A boring was driven to a depth of 15.3 feet below mean low water and indicated a 9-foot stratum of coarse sand, gravel and boulders extended to 2.8 feet below mean low water under which there were strata, each 3 feet thick, of coarse yellow sand, loose blue clay, gravel with a little hard sand and clay, and hard yellow sand and gravel with a little clay. Borings along the east side of the point indicated a stratum of sand, gravel and boulders, generally 1 foot thick, overlies a stratum of peat and silt, which in turn overlies strata of blue and yellow clay with a little sand. The peat and silt stratum varied from 7 to 20 feet in depth.

25. Probings. - Probings were taken by hand bar along the low water line on July 22, 1946 at locations indicated on Plate B-1. At

Profile 1, mouth of the Saugus River, a penetration of 7 feet was attained through fine sand and mud. At Profile 2, the base of the Point of Pines, a penetration of 7 feet was attained through sand and light gravel. At Profile 3, a penetration of 7 feet was attained through sand and clay. At Profile 4, a penetration of 0.6 feet was attained through sand and gravel and 3.4 feet through hard-packed sand.

26. Samples. - Samples of the material lying between 2 to 4 inches below beach elevations at the low water line were taken on April 24, 1946 at locations indicated on Plate B-1. The median diameters were found to be as follows:

Location	Median Diameter (mm.)
Profile 1	0.09
Profile 2	0.14
Profile 3	0.16
Profile 8	0.15

27. Wind. - A wind diagram compiled from observations of the U. S. Weather Bureau at Boston, Massachusetts, 1927-1937, and the yearly cumulative average ocean winds compiled from records of the U. S. Navy Hydrographic Office for the 5-degree squares nearest Revere Beach and other Metropolitan District Beaches are shown on Plate 2. An examination of these two diagrams indicates that, of the winds which blow over significant fetches of ocean before reaching the area, those from the northeast quadrant are prevailing and predominant. Revere Beach is afforded a degree of protection from the prevailing and dominant northeast winds by the Nahants and their connecting tombolo by limiting the fetch over which the wind can act. The less frequent east-southeast storms, therefore, have the greatest effect upon this beach.

28. Tides. - The mean range of tide at Revere Beach, computed from the accepted value at Boston, Massachusetts by application of a factor determined by the U. S. Coast and Geodetic Survey, is 9.0 feet. The

heights of extreme tides have not been recorded at Revere Beach, but those observed over a long period of record at Boston Harbor provide an excellent indication of the magnitude of fluctuations from the mean. At Boston Harbor the predicted spring tides range up to 12.0 feet; actual heights of extreme tides having been recorded up to 15.0 feet above mean low water.

29. Storms and Their Effects. - a. Hurricanes. - The paths of all hurricanes (defined as those with a central pressure of 29.0 inches or lower, and winds near the center of more than 60 miles per hour in some points in the path) which have struck within a 150-mile radius of Revere Beach between the years 1874 and 1944 have been extracted from the book, "Hurricanes," by Ivan R. Tannehill and various other sources and plotted on Plate 2. An examination of this plate shows that between 1874 and 1945, a period of 71 years, 32 tropical storms of hurricane intensity have passed within a 150-mile radius of the beach.

b. Gales. - A summary of the record of winds of gale force or greater, compiled from records of the U. S. Weather Bureau at Boston, Massachusetts, covering the 75-year period 1870 to 1945, inclusive, is given in the following table:

DIRECTION OF GALES

1870-1945 (incl.)

Direction	Number of Gales	Percent of Total Gales
North	3	2
Northeast	80	50
East	9	6
Southeast	14	9
South	12	7
Southwest	15	9
West	13	8
Northwest	14	9
	160	100

The following table, based upon the gale record summarized above, indicates the number of days that gales from various directions may be expected during a 100-year period.

GALE FREQUENCY BY DIRECTION

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	TOTAL
Number of days observed 1870 to January 1946	4	131	9	15	12	20	16	18	225
Frequency in days per 100 years	5	175	12	20	16	27	21	24	300

During a 100-year period 175 gales, comprising 58 percent of all gales, may be expected from the northeast. Only 32 gales (11 percent of all gales) are to be expected from both the east and southeast.

c. Effect. - Storm damage along Revere Beach results from the action of wind-driven waves and their induced currents, and its severity is directly dependent upon the velocity and direction of the wind and the tidal stage during the storms. The configuration of the coast in the Revere area is such that the beach is acted upon only by waves originating from north through east to south quadrants. The analysis of the wind diagrams indicate that winds from the northeast quadrant have great preponderance, in regard to both duration and velocity, over other winds producing waves that can act upon the shore line of the northern part of Massachusetts. The records of gales indicate that storms from the northeast have a much greater frequency and duration than storms from other quadrants. The former Nahant Islands and the connecting tombolo affords partial protection to Revere Beach from the direct attack of dominant northeasterly winds; the direct attack being limited by the 2-3 mile fetch across Broad Sound to Nahant. Revere Beach, however, is subject to the attack of northeast storm waves refracted by Nahant and by headlands south of the beach.

The storms having the greatest effect upon Revere Beach are those with a southeasterly component, approaching over unrestricted ocean areas.

30. The study area is partly protected by discontinuous sea-walls of varying design along the northerly end near the Point of Pines section and along the southerly end in the amusement section. Surf normally occcurs on the beach; the action being greatly intensified under storm action. Serious storm damage has not occurred on this beach in recent years; such damage consisting of flooding the road along the shore line with the deposition of sand, stone and debris on the road, small washouts in the rear of walls and minor damage to shore protection structures. Heavy seas are reported to have washed over the boulevard during a storm in 1931, apparently the storm of March 5 and 6, with waves hitting the police station. Existing damaged condition of structures appears to be the cumulative result of successive storms, wave action and freezing and not the result of any one particular storm. This damage consists of the spalling of concrete surfaces, particularly at joints, damage to concrete copings on walls, and cracking, spalling and disintegration of steps and joint caps on stepped sea-walls. The greatest storm damage in the area has been experienced in the Roughan's Point area, immediately south of the Cherry Island Bar. The storm of December 5, 1945 washed large cap stones from the outer end of Cherry Island Bar Breakwater. Heavy storms flood low coastal roads in the Point of Pines area and destroy pavements.

31. Storm damage in the area as reported in the press in recent years is as follows:

a. Jan. 26-29, 1933. - Northeast storm. Waves were reported to be sixty to seventy-five feet high, with spray crossing the road. The shock of waves hitting sea-walls was felt one mile inland. No damage was

done to sea-walls, but walls were washed over and backfill was removed and sidewalks adjacent to walls were undermined. Large amounts of boulders were washed onto the sidewalk in the Crescent Beach Area. At Point of Pines, the road was buried under two feet of cobbles, stone, and sand, and 300 feet of road was undermined. At Roughan's Point, twelve houses were destroyed or damaged. The northern part of Roughan's Point prograded about twenty feet and the southern part eroded about one hundred feet.

b. Nov. 17-18, 1935. - Northeast storm. The only coastal damage in the Boston area was the loss of two cottages in the Roughan's Point area.

c. Mar. 17-18, 1938. - Northeast storm. Some erosion occurred adjacent to the toe of the stepped sea-wall near Northern Circle. No damage occurred to structures. Roughan's Point area was adequately protected by the new sea-wall.

d. Nov. 5, 1939. - Northeast storm. Waves broke over sea-walls.

e. Feb. 22, 1940. - High tides following a northeast storm. Waves at Winthrop were fifty feet high.

f. Apr. 22-23, 1940. - Northeast storm. Slight damage was experienced at the amusement area with wave wash passing over the road. At Point of Pines, houses and yards were flooded and undermined. At Roughan's Point, waves broke over the sea-wall and washed out one hundred fifty feet of road.

g. Jan. 12, 1941. - Heavy wave action, due to offshore gales, resulted in spectacular surf but caused little damage.

h. Oct. 31, 1947. - Northeast storm which raised a predicted 10.8 tide to 12.5, flooded Roughan's Point. Houses and cottages were sandbagged to prevent damage.

i. Nov. 9, 1947. - Revere Parkway was strewn with sand and stones during Northeast storm.

j. Nov. 12, 1947. - Northeast storm flooded Roughan's Point area.

32. The following report of the effects of the storm of November 28-30, 1945 was prepared by the District Engineer, Boston, Massachusetts, and is based upon field inspection. This storm was 53 hours in duration, in which the wind attained a maximum velocity of 68 m.p.h. The storm came at a neap range of tides in which predicted tides at Boston, Massachusetts, were from 8.4 to 8.9 feet. The recorded tides in Boston were 9.1 to 12.5 feet, which approached and exceeded maximum normal tides. This storm caused extensive damage all along the coast.

a. South of Cherry Bar, in the Roughan's Point area, five hundred acres of residential property were flooded behind the sea-wall and one hundred fifty families were evacuated. Streets were littered with sand, stone, and debris and pavements were washed out. Flood waters rose to the level of the first floors of many houses.

b. In the Point of Pines area, Rice Avenue was washed out for a distance of 1,000 feet, with the pavement being broken up and the road bed being lowered about twelve inches. At the northern end of the washed-out area, riprap was dislodged and a concrete filled, timber crib sea-wall severely damaged. Adjacent property suffered no damage except the flooding of lawns.

c. Between the Northern Circle and the amusement area, beach elevations were lowered six to twelve inches, exposing a concrete bulkhead which was previously buried. The dune fronting the retaining wall was cut back about one and one-half (1-1/2) feet. In the amusement area, stone cobbles and sand were driven over the stepped sea-walls and onto the street. There was no apparent damage to structures. Minor washouts occurred to the walk paralleling the beach.

33. It is to be noted that the above reports detail damage occurring under the impact of northeast storms in the Point of Pines area which is at the head of the bay and well protected from direct assault from such storms buffeting the open coast. In the study of Lynn-Nahant Beach it was noted that during northeast storms, considerable damage also occurs along the inner side of the Nahant tombolo, which area lies across Lynn Harbor from Point of Pines and is well protected from all storms having other than south or southeasterly components. This damage is due in part to the impounding of storm waters in the bay. Severe storm damage is reported at Roughan's Point, the area immediately adjacent to Cherry Island Bar at the southern limit of this study. Roughan's Point lies outside of protection afforded by Nahant.

V. CHANGES IN BEACH AND OFFSHORE AREAS

34. Changes in Shore Lines and Profiles. - The changes which have been effected on the beach are indicated by the comparison of mean high and low water lines shown on Plate A-2 and the comparative profiles shown on Plates B-2, B-3, and B-4. The mean high and low water lines cover the entire beach while the profiles cover only the Metropolitan District Commission's reservation, Profiles 2 - 16 inclusive. The indicated changes are not to be correlated with any given shore protective structure since these structures have been erected at various times throughout the periods included by the recorded water lines and profiles. However, the changes between Profiles 2 and 4, as indicated by the comparative profiles, have been influenced by fill placed between 1904 and 1906 for the construction of the boulevard. Highway elevations were raised 3 - 5 feet at that time and the seaward side of the fill extended onto the beach with a slope of 1 on 10.

35. Shore Line Changes. - a. - The plot of shore line changes was developed from original surveys made by the U. S. Coast and Geodetic Survey in 1849, 1847-50, 1893-94, 1919, and 1944 and from the survey made for this study in 1945-46 by the District Engineer. The 1944 survey was made by aerial photographic methods and it is noted that its plot indicates some changes which are greater than have actually occurred, and hence shore lines for this survey are to be considered only as indicative of general trends.

b. Accretion has been effected along the Saugus River, Profiles 26 - 28, since 1849 with both the mean high and low water lines moving, on the average, 50 feet toward the river.

c. The northerly half of the seaward beach of Point of Pines, adjacent to the mouth of the Saugus River, has experienced both erosion and accretion, though since 1893-94 there has been accretion with the mean high water line moving an average of 150 feet seaward and the mean low water line moving an average of 500 feet seaward.

d. The southerly half of the Point of Pines beach has also undergone periods of erosion and accretion. The trend since 1893-94 has been erosion along the mean high water line and accretion along the mean low water line, with the low water line moving seaward an average distance of 650 feet.

e. Along the Metropolitan District Commission's reservation both accretion and erosion occurred at the mean high water line. A more detailed study of this movement may be made by comparison of the position of mean high water as indicated on the profiles for the years 1900, 1904, 1910, 1941, and 1945 shown on Plates B-2 to B-4 and intermediate profiles between Profiles 2 and 4 not included on these plates. The net result of the movements indicated by these profiles is as follows:

Profiles	Average Movement in Feet	Reaction
2-3	25	Erosion
3-4	13	Accretion
4-12	23	Erosion
12-15	34	Accretion

The movement of mean low water lines indicate a net general accretion along the entire reservation since 1847. For approximately 3,000 feet south of Profile 2, there was erosion averaging 300 feet in width until 1893, when a period of accretion set in. This has resulted in an average seaward movement of 200 feet in the low water line and the formation of

a bar about 400 feet wide and 2200 feet long just seaward of the mean low water line. In the area of Profiles 3 and 4 there has been a constant accretion, which has moved the mean low water line about 400 feet seaward of its 1849 position, with 300 feet of this movement taking place since 1893. Between Profiles 4 and 16 there was a shoreward movement of the low water line averaging about 50 feet between 1847 and 1893. This erosion was followed by a seaward movement of the mean low water line averaging 200 feet between Profiles 4 and 12 and 500 feet between Profiles 12 and 16. It is to be noted that the extremely flat beach near low water levels, generally 1 on 400, results in great horizontal movements of contours with small changes in elevation.

f. The position of the mean high and low water lines indicate continuous accretion along the northerly side of Roughan's Point, Profiles 16 - 19, since 1893. This accretion has been the greatest between Profiles 16 and 17, which are at the base of the point, and averages 200 feet at high water and 400 feet at low water. There was a period of erosion in this area prior to 1893 when the mean high water line receded about 150 feet between 1849 and 1893.

g. Constant erosion at and above mean high water level has reduced Cherry Island bar to such elevations as to be covered at mean high water. The 1945-46 mean high water line follows along the mainland coast line whereas the 1849 and 1893 mean high water lines outline the bar as extending to the inner end of the breakwater. Data was not available for previous positions of low water around the northerly face of the bar, but the position of the 1893 and 1946 mean low water lines on the south side of the bar indicate there has been accretion averaging about 300 feet in this area.

36. Changes in Profiles. - a. General. - The Metropolitan District Commission made 4 surveys of profiles spaced 500 feet apart along the entire length of its reservation, the surveys being made in 1900, 1904, 1910, and 1941, with the 1941 survey omitting the five most northerly profiles. The commission used the highway centerline as a base line and designated their profiles by the highway survey stations at which they were taken, each station being an even multiple of 100 feet, measured from the center of Eliot circle. In 1945 and 1946 the District Engineer laid out survey work for this study so that Profiles 2 - 16 inclusive, repeated certain of the Commission's profiles. Profile 2 coincides with the most northerly of previously surveyed profiles, being located at station 135+00 . Profile 3 is 3500 feet south of Profile 2, being located at station 90+00. Profile 4 is 3000 feet south of Profile 3, being located at station 60+00. Profiles 5 - 16 inclusive are located at stations 500 feet apart with Profile 5 being located at station 55+00 and Profile 16 being located at station 0+00 in the center of Eliot Circle. Typical plots of these surveys are shown on Plates B-2, B-3, and B-4. These plots indicate that both erosion and accretion have been effected at various times along the beach.

b. Vertical and Horizontal Changes. - In general the horizontal movement of the mean high-water line may be considered as indicative of the processes effected in and above the upper tidal ranges. The movement of the mean low water line cannot be considered as indicative of the processes effected since the flat slope of the lower foreshore area and adjacent offshore area, generally between 1 on 300 and 1 on 400, allows only a slight change in elevation to move the contours hundreds of feet horizontally. Changes of 300 to 400 feet

are thus indicated at the mean low water line in 4- and 6-year periods. The horizontal movement of the mean high and low water lines must thus be interpreted in the light of corresponding vertical changes in beach elevations. These changes are generally as described below:

(1) Above mean high water the net change since 1900 has been erosion north of Profile 12 and accretion south of Profile 13. The maximum variation in beach elevations in erosion areas has been 2 to 4 feet, except that at Profile 2 the maximum change is 6 feet. The maximum changes in beach elevations in accretion areas have varied between 1 to 11 feet, the greatest changes reflecting the presence of the stone beach ridge.

(2) Between mean high and mean low water levels the changes since 1900 have varied from erosion to accretion. North of Profile 12 erosion has been generally effected in the upper tidal ranges and accretion in the lower tidal ranges. The maximum erosion experienced varies from 2 to 4 feet vertically. The maximum accretion varies from 2 to 3 feet vertically without appreciable accretion occuring in the vicinity of Profiles 4 and 5. South of Profile 13, accretion has been effected throughout the tidal range with the maximum vertical changes in elevations being between 5 and 6 feet.

(3) Below and adjacent to the mean low water level, the net change since 1900 has been erosion north of Profile 10 and accretion south of Profile 11. The maximum vertical movement of beach levels has been 2 to 3 feet in erosion areas and 1 to 2-1/2 feet in accretion areas.

(4) These changes may be generally summarized for all levels as erosion north of Profile 12 and accretion south of Profile 13.

37. Volumetric Changes in Beach. - a. - The extent of changes effected upon the beach between Profiles 2 and 15 is indicated in Tables A and B of paragraph 38 which show volumetric changes effected between the position of the 1900 mean low water line and the seaward edges of the sidewalks and seawalls. The width of the beach between the 1900 mean low water line and the seawall sidewalk line varies from 290 feet to 1430 feet and averages 685 feet. The data presented in Tables A and B have been summarized in Tables C, D, and E of paragraph 38 to show the changes effected at various sections of the beach. The sections are as follows:

(1) Profiles 2 - 3. - Northerly 4500 feet of Metropolitan District Commission Reservation, averaging 900 feet in beach width.

(2) Profiles 3 - 4. - Central 3000 feet of Metropolitan District Commission Reservation, averaging 850 feet in beach width.

(3) Profiles 4 - 12, inclusive. - Southerly 4000 feet of Metropolitan District Commission Reservation, averaging 390 feet in beach width.

(4) Profiles 12 - 15, inclusive. - South end of Metropolitan District Commission Reservation, 1500 feet long, averaging 460 feet in beach width.

b. The computations are based upon the profiles described in paragraph 36. It is to be noted that the spacing of Profiles 4 to 15 allows computations to be based upon sections 500 feet apart while the spacing of Profiles 2 and 3 results in computations being based upon sections 4500 and 3000 feet apart. It was found that computations made on intermediate profiles between Profiles 3 and 4 for the years 1900, 1904 and 1910 balanced with the total volumes computed

between the primary profiles, and are thus shown in the tables. Between Profiles 2 and 3, however, it was found that totals based upon the intermediate profiles for the years 1904 and 1910, were 18 and 32 per cent lower than required to balance with the totals computed directly between the primary profiles. Since all surveys did not extend from the seawall sidewalk line to the position of 1900 mean low water, it was necessary to interpolate certain profiles to obtain complete computations. Computations were not made for periods involving the 1941 profiles since sufficient profiles were not available to make complete computations between Profiles 2 and 15.

38. Tables A, B, C, D, and E, showing volumetric changes along 2.5 miles of beach between Profiles 2 and 15 and within a beach width determined by the front of the sidewalks and seawalls and the position of the 1900 mean low water line indicate:

a. The over-all change effected on the beach during the period of record, 1900 to 1946, was a loss of 110,000 cubic yards of material.

b. Erosion and accretion has been effected at various times at most positions along the beach, but the net result has been erosion for all but the southerly 1500 feet of the beach. Between Profiles 2 and 12, a distance of 11,500 feet, there was a net erosion of 170,100 cubic yards of material between 1900 and 1946, while between Profiles 12 and 15 there was a net accretion of 60,100 cubic yards.

c. The beach between Profiles 2 and 12 has not suffered continuous erosion nor has the rate of erosion been constant along the entire beach. The most northerly part of the beach between Profiles 2 and 3 suffered erosion of 74,700 cubic yards between 1900 and 1904 and 53,400 cubic yards between 1904 and 1910. Since 1910 this area

has enjoyed an accretion of 39,000 cubic yards. However, the net effect in this area has been 89,100 cubic yards of erosion since 1900 which is greater than that experienced in other sections of the beach.

d. The processes effected along the central part of the beach between Profiles 3 and 4 have been similar to those effected between Profiles 2 and 3, but the quantities have been very much smaller, being only 1900 cubic yards erosion between 1900-1904, 28,600 cubic yards erosion between 1904 - 1910, and 6,600 cubic yards accretion between 1910 and 1946. The net change in the area has been 23,900 cubic yards erosion, which is only 27% of that experienced between Profiles 2 and 3.

e. The beach between Profiles 4 and 12 enjoyed 15,000 cubic yards of accretion between 1900 and 1904 while the northerly areas were eroding. This process changed to erosion between 1904 and 1910 during which time there was a loss of 51,700 cubic yards. This erosion continued between 1910-1946 when the loss was 20,400 cubic yards. It is significant to note that while this section of beach suffered erosion during the 36 year period, 1910 to 1946, when all other sections enjoyed accretion, the erosion was only 39% of that suffered in the preceding 6 year period, 1904 to 1910. The net result in this area has been erosion of 57,100 cubic yards between 1900 and 1946.

f. The beach between Profiles 12 and 15 has constantly enjoyed accretion, with the rate of accretion being the greatest during the period when the rate of erosion was greatest between Profiles 2 and 12. Between 1900 and 1904 there were 2700 cubic yards accretion while the northerly beach lost 61,600 cubic yards. Between 1904 and 1910 the accretion increased to 28,600 cubic yards while the erosion of the northerly beach increased to 133,700 cubic yards.

g. The average annual rate of change has varied greatly during the several periods. Between Profiles 2 and 3 the rate of change has varied from 18,675 cubic yards erosion per year for a 4 year period to 1083 cubic yards accretion per year for a 36-year period. Between Profiles 3 - 4 the rate of change per year has varied from erosion of 4767 cubic yards for a 6-year period to accretion of 183 cubic yards for a 36-year period. Between Profiles 4 and 12 the rate has changed from 3750 cubic yards accretion per year for a 4-year period to 8617 cubic yards of erosion per year for a 6-year period. The net result between Profiles 2 - 12 since 1900 has been an annual loss of 3698 cubic yards, but for the past 36 years there has been an annual gain of 700 cubic yards per year. Between Profiles 12 and 15 there has been a constant accretion averáging 1307 cubic yards per year for 46 years. This annual accretion was greatest between 1904 and 1910 when the annual gain was 4767 cubic yards per year.

h. In the erosion area, Profiles 2 - 12, there has been an annual loss of 1 cubic yard of material per linear yard of beach for a 46-year period, while in the accretion area there has been an annual gain of 2.6 cubic yards per linear yard of beach. It is to be noted that between Profiles 2 and 12 the net result for the past 36 years has been a gain of 0.2 cubic yards of material per linear yard of beach.

i. Volumetric computations show that accretion has occurred in the area between Profiles 2 and 12 while inspection of plotted profiles indicate that general erosion has occurred in and above the upper tidal ranges.

TABLES OF VOLUMETRIC CHANGES

Volumes are given in cubic yards with accretion indicated by + and erosion by -. All volumes are computed for the sector between the line of seawalls and sidewalks and the position of mean low water in 1900.

TABLE A - TOTAL VOLUMETRIC CHANGES

Location		Total Change in Cubic Yards			
Profile Numbers	Highway# Station	1900-1904	1904-1910	1910-1946	1900-1946
2 - 3	135-90	- 74,700	- 53,400	+ 39,000	- 89,100
*3 - 4	90-60	- 1,900	- 28,600	+ 6,600	- 23,900
4 - 5	60-55	+ 1,400	- 4,000	- 7,600	- 10,200
5 - 6	55-50	+ 2,200	- 3,700	- 7,700	- 9,200
6 - 7	50-45	+ 1,600	- 5,000	- 5,600	- 9,000
7 - 8	45-40	+ 1,900	- 5,300	- 4,300	- 7,700
8 - 9	40-35	+ 2,500	- 11,100	+ 2,500	- 6,100
9 - 10	35-30	+ 2,300	- 12,400	+ 3,900	- 6,200
10 - 11	30-25	+ 2,200	- 7,100	- 1,000	- 5,900
11 - 12	25-20	+ 900	- 3,100	- 600	- 2,800
12 - 13	20-15	+ 200	+ 2,400	+ 3,200	+ 5,800
13 - 14	15-10	+ 1,000	+ 10,800	+ 9,300	+ 21,100
14 - 15	10- 5	+ 1,500	+ 15,400	+ 16,300	+ 33,200
Total 2 - 15	135- 5	- 58,900	-105,100	+ 54,000	-110,000
	* Intermediate changes between Profiles 3 and 4.				
3	90-85	+ 800	- 1,100		
	85-80	+ 900	- 2,700		
	80-75	- 1,200	- 5,700		
	75-70	- 1,000	- 7,000		
	70-65	- 1,100	- 6,800		
4	65-60	- 300	- 5,300		
Subtotal 3 - 4	90-60	- 1,900	- 28,600		

\# Distance from Profile 16 at Eliot Circle, measured in units of 100 feet along centerline of Revere Beach Reservation Drive.

TABLE B - AVERAGE ANNUAL VOLUMETRIC CHANGES

Location		Average Annual Change in Cubic Yards per Year			
Profile Numbers	Highway# Station	1900-1904	1904-1910	1910-1946	1900-1946
2 - 3	135-90	- 18,675	- 8,900	+ 1,083	- 1,937
* 3 - 4	90-60	- 475	- 4,767	+ 183	- 519
4 - 5	60-55	+ 350	- 667	- 211	- 222
5 - 6	55-50	+ 550	- 617	- 214	- 200
6 - 7	50-45	+ 400	- 833	- 155	- 196
7 - 8	45-40	+ 475	- 883	- 119	- 167
8 - 9	40-35	+ 625	- 1,850	+ 70	- 133
9 - 10	35-30	+ 575	- 2,067	+ 108	- 135
10 - 11	30-25	+ 550	- 1,183	- 28	- 128
11 - 12	25-20	+ 225	- 517	- 17	- 61
12 - 13	20-15	+ 50	+ 400	+ 89	+ 126
13 - 14	15-10	+ 250	+ 1,800	+ 258	+ 459
14 - 15	10- 5	+ 375	+ 2,567	+ 453	+ 722
Total 2 - 15	135- 5	- 14,725	- 17,517	+ 1,500	- 2,391
	* Intermediate Changes Between Profiles 3 and 4.				
3	90-85	+ 200	- 183		
	85-80	+ 225	- 450		
	80-75	- 300	- 950		
	75-70	- 250	- 1,167		
	70-65	- 275	- 1,133		
4	65-60	- 75	- 884		
Subtotal 3 - 4	90-60	- 475	- 4,767		

Distance from Profile 16 at Eliot Circle, measured in units of 100 feet along centerline of Revere Beach Reservation Drive.

TABLE C - TOTAL VOLUMETRIC CHANGES BY BEACH AREAS

Beach Area		Total Changes in Cubic Yards			
Profile Numbers	Dist.in Ft. Between Profiles	1900-1904	1904-1910	1910-1946	1900-1946
		General Erosion Area			
2 - 3	4,500	- 74,700	- 53,400	+ 39,000	- 89,100
3 - 4	3,000	- 1,900	- 28,600	+ 6,600	- 23,900
4 - 12	4,000	+ 15,000	- 51,700	- 20,400	- 57,100
Total 2 - 12	11,500	- 61,600	-133,700	+ 25,200	-170,100
		General Accretion Area			
12 - 15	1,500	+ 2,700	+ 28,600	+ 28,800	+ 60,100

TABLE D - AVERAGE ANNUAL VOLUMETRIC CHANGES BY BEACH AREAS

Beach Area		Average Annual Change in Cubic Yards Per Year			
Profile Numbers	Dist.in Ft. Between Profiles	1900-1904	1904-1910	1910-1946	1900-1946
		General Erosion Area			
2 - 3	4,500	- 18,675	- 8,900	+ 1,083	- 1,937
3 - 4	3,000	- 475	- 4,767	+ 183	- 519
4 - 12	4,000	+ 3,750	- 8,617	- 566	- 1,242
Total 2 - 12	11,500	- 15,400	- 22,284	+ 700	- 3,698
		General Accretion Area			
12 - 15	1,500	+ 675	+ 4,767	+ 800	+ 1,307

TABLE E - AVERAGE ANNUAL VOLUMETRIC CHANGES
PER UNIT LENGTH OF BEACH

Beach Area		Average Annual Change in Cubic Yards Per Linear Yard of Beach			
Profile Numbers	Dist. in Yds. Between Profiles	1900-1904	1904-1910	1910-1946	1900-1946
		General Erosion Area			
2 - 3	1,500	- 12.5	- 5.9	+ 0.7	- 1.3
3 - 4	1,000	- 0.5	- 4.8	+ 0.2	- 0.5
4 -12	1,333	+ 2.8	- 6.5	- 0.4	- 0.9
Total 2 -12	3,833	- 4.0	- 5.8	+ 0.2	- 1.0
		General Accretion Area			
12 -15	500	+ 1.4	+ 9.5	+ 1.6	+ 2.6

39. Offshore Depth Changes. - a. General. - Plates A-3 to A-5 show the 6, 12, and 18-foot offshore depth curves developed in the area by the U. S. Coast and Geodetic Survey from surveys made in the years 1846-47-48, 1853-54, 1892, 1895, and 1945. Contours at the mouth of the Saugus River developed from profiles surveyed by the District Engineer in 1945-46 are also shown. In other areas the position of the 6 and 12-foot depths have been plotted where profiles reached such depths. The discontinuous nature of the contours do not allow determination of volumetric changes, but do indicate the general changes effected in the area. These changes may be discussed for the same sectional areas as were the shore line changes and volumetric changes above mean low water elevation.

b. Saugus River-Profiles 28 to 24 and 1. - The only available contours are those developed from the 1946 survey by the District Engineer. The 6-foot curves for the river channel align quite well with the 6-foot contours for the 1892 survey between Profiles 1 and 2 indicating that there has been little change in the area. The location of the 18-foot contour suggests a scouring action just off of the extreme point of Point of Pines.

c. Point of Pines-Profiles 1 to 2. - The location of the 6-foot contours are given for two years 1853-54 and 1892. These contours indicate a realignment of the channel to Saugus River was accomplished between these years resulting in a 500-foot seaward movement of the channel in the vicinity of Profile 2. The position of the 1946 channel in the river proper indicates that the 6-foot contour has been stable since 1892. The 12 and 18-foot contours are 7000 and 8500 feet from the shore and cross the entrance to Lynn Harbor. The 12-foot contour moved seaward approximately 500 feet

between 1846 and 1853. Between 1853 and 1892 the erosion and accretion nearly balanced each other. The 18-foot contour experienced accretion between 1846 and 1853, and erosion between 1853 and 1892 with the result that the 1892 contour is on the average about 250 feet landward of the 1846 contour.

d. North End of Revere Beach - Profiles 2-3. - Between 1846 and 1853 the 6-foot contour moved, on the average, 1000 feet shoreward, and between 1853 and 1892 returned to almost its initial position. The location of the 6-foot depths on profiles 2 and 3 in 1946 indicated that the present contour is between 500 feet and 1000 feet landward of the 1846 and 1892 positions. The 12-foot contour generally moved 350 feet seaward between 1846 and 1853. Between 1853 and 1892 this contour moved landward 200-500 feet. The 12-foot depth on Profile 3 in 1946 was about 500 feet landward of its position in 1892. The 18-foot contour moved landward an average distance of 400 feet between 1846 and 1853 and an average distance of 200 feet between 1853 and 1892.

e. Central Section of Revere Beach - Profiles 3-4. - There was accretion along the 6-foot contour between 1846 and 1892 resulting in a seaward movement of the contour of between 500 and 1000 feet. This movement was not continuous as adjacent to Profile 3 there was erosion prior to 1853, which effect resulted in a maximum seaward movement of 2200 feet for the 6-foot contour in 39 years, 1853-1892. The position of the 6-foot depth in 1946 on Profiles 3 and 8 indicated that the present contour has moved landward of the position of 1846 contour and the movement since 1892 has generally been between 700 and 1200 feet. The movements of the 12-foot contour followed the pattern of the 6-foot contour movement with the result that the present location of the 12-foot depth curve is from 300 to 800 feet landward

of its position in 1892 and about 250 feet landward of its position in 1846. The present position is indicated by the 12-foot depth located on Profile 3 and the position of the 1945 contour on Profile 4. The movement of the 18-foot contour is shown only for two years, 1846 and 1892. During the period between these years the 12-foot contour moved 200 to 400 feet seaward.

f. South End of Revere Beach - Profiles 4 - 15. - The dominant movement of the 6-foot contour has been landward, averaging 500 feet between 1846 and 1892 and averaging 600 feet between 1892 and 1945. The 12-foot contour has experienced accretion and erosion, moving 100 to 500 feet seaward between 1846 and 1892 and moving landward an average of 250 feet between 1892 and 1945. The net movement during the period of record has been accretion while for the past 53 years the movement has been erosion. The 18-foot contour has experienced erosion and accretion. Between 1846 and 1892 there was a general seaward movement of 200 feet. Between 1892 and 1945 there has been an average landward movement of 100 feet.

g. Roughan's Point - Profiles 15 - 20. - The dominant movement of the 6-foot contour has been seaward. Between 1846 and 1892 this movement amounted to 200 to 400 feet. Between 1892 and 1945 there has been a seaward movement varying up to 500 feet adjacent to Profile 20 while a landward movement of the same magnitude has been effected adjacent to Profile 15. The 12-foot contour moved seaward an average distance of 400 feet between 1846 and 1892. Between 1892 and 1945 there has been a landward movement varying up to 700 feet. In addition seven holes having depths in excess of 12 feet, have been formed landward of the position of the contour in 1846. The movement of the 18-foot contour has been both landward

and seaward. Near Profile 15 the net result since 1846 has been erosion with the contour in 1945 being about 200 feet landward of the 1846 position. Adjacent to Profile 20, there has been constant accretion, the profile moving seaward an average of 200 feet between 1846 and 1892, and an average of 500 feet between 1892 and 1945.

40. The discussions of offshore contours set forth in the preceding paragraph 39 may be summarized as follows:

a. The Saugus River and the ocean beach fronting the Point of Pines are stable in offshore areas.

b. The north end of Revere Beach is experiencing erosion at all offshore depths.

c. The central section and southend of Revere Beach have experienced erosion and accretion, with erosion dominating since 1892.

d. At Roughan's Point, and the area of Cherry Island Bar, there have been accretion at both the 6 and 18-foot depth curves while there has been erosion at the 12-foot contour.

41. Littoral Drift. - a. General. - The littoral drift along Revere Beach varies from a north-south to a south-north drift in accordance with the direction of the forces producing the drift. The dominant drift along the open coast in this area is from north to south, being produced by waves set up by the dominant northeast storms, winds and swells. Revere Beach, however, is well protected from direct attack from the dominant northeast forces by the two Nahant Islands and the tombolos tying them together and to the mainland and the littoral drift along Revere Beach is produced by refracted waves and swells which move both north and south along the beach.

b. Refracted Waves. - Waves from the northerly quadrant are refracted around Big Nahant and cross the sound to Revere Beach and split to travel both north and south along the beach. The northerly movement is evidenced by the extensive damage which is wrought along the westerly side of the Nahant Tombolo during the northeast storms. This northerly movement has created a drift which transports materials to build a large dune on the beach on the south side of the mouth of the Saugus River which now buries about 250 feet of the concrete seawall at the mouth. The southerly movement along Revere Beach is evidenced by the high stone beach ridges which form at the base of Roughan's Point. Waves of considerable intensity are required to construct such ridges and the location of the ridges indicates that the building force must have had a northerly component.

c. Volumetric Changes. - The analysis of the movement of materials as indicated by the tables of volumetric changes set forth in paragraph 38 indicates that within the area of the comparative profiles, Profile 2 - 15 inclusive, there has been a southerly drift. There have been periods of erosion and accretion along the beach between Profiles 2 and 12 but there has always been accretion of material south of this area between Profiles 12 and 15. Since 1900 the loss of materials in the erosion area has amounted to 170,100 cubic yards and the gains in the accretion area has amounted to 60,100 cubic yards. These quantities show a strong southerly movement of materials within the area studied.

d. Littoral Drift at Roughan's Point. - Cherry Island Bar has been subject to erosion for a great period of time, making available materials for beach building. Roughan's Point in itself is a result of such erosion, being a cuspate tombolo connecting the former

island to the mainland. Plate A-2 showing the movement of shorelines, indicates that in 1894 the mean high water line extended around the bar while in 1919 the same line did not extend around the bar. During this period the bar was reduced to an elevation that allows high water to cover and move materials over it. In 1932 a wall was built south of Roughan's Point to close a minor inlet to the Belle Isle Inlet marshlands. It is reported that shortly after that time, stones appeared on the sandy south end of Revere Beach and that Roughan's Point commenced to erode. In 1936, a substantial wall was constructed along the easterly side of the point and a stone mound was constructed along the seaward half of the northerly side of the point. The mound formed a jetty at the tip of the point and a groin was built from the inner end of the mound. In 1941 this mound was continued to join an existing wall. The stones have, however, continued to pile up on the south end of Revere Beach. The jetty and groins have collected deposits which indicate that materials move northerly around the point to Revere Beach. There are greater amounts of materials on the south side of the jetty at Profile 20 and on the east side of the groin between Profiles 17 and 18, indicating a movement of materials northerly around the point. The groin between Profiles 16 and 17 is subject to a local scouring action which prevents natural deposition of material on its easterly side. It is evident that materials do move northerly around the point, but it must be noted that only forces acting in a southerly direction could build up the stone beach ridges at the base of Roughan's Point to the heights attained.

e. Geological Growth of Beach. - Revere Beach was constructed by the distribution of glacial till from Young's Hill, Beachmont and Cherry Island and of outwash sands and gravels from the areas of

Oak Island and Revere Street. Cherry Island was tied to the mainland by a cuspate tombolo to form Roughan's Point, with the island later eroding to form Cherry Island Bar. The materials from these sources may have moved in both directions, north and south. However, since all sources are south of Profile 3, the northerly end of Revere Beach and the Point of Pines must have been built under dominant northerly drifting between Profiles 3 and 1. The present tip of the Point of Pines is about 4000 feet north of the first beach to occupy a position close to the present beach.

f. Sources of Beach Building Materials. - There are no present onshore sources of materials for building beaches since the existing walls, bulkheads, and riprap revetments and mounds cut off all such sources from wave attack. The elevation of the top of the crest of Cherry Island Bar has been lowered so as to be acted on by waves. This erosion has amounted to 0.5 to 3.0 feet vertically since 1906, with the greatest erosion taking place near the shore line of Roughan's Point. It is evident therefore, that the materials transported along Revere Beach comprise existing beach materials which are being reworked by littoral currents, and materials moving around Roughan's Point and off Cherry Island Bar.

VI. EXISTING PROTECTIVE STRUCTURES
(Plate B-1, Figures B-1 to B-3)

42. Structures and Ownership. - The coast line of Revere Beach from the Saugus River to Roughan's Point is lined with a discontinuous series of sea-walls, pavilions, bulkheads, retaining walls, and riprap shore protection. The retaining walls were constructed principally to maintain the seaward edge of the boulevard. A complete description of all structures is contained in Appendix I, supplemented by details of principal structures shown on Plate B-1 and pictured on Figures B-1 to B-3. The net effect of these structures is to afford protection to the extreme end of the Point of Pines; continuous protection to Revere Beach from a point about 1700 feet southerly of Profile 1 to a point adjacent to Profile 8; and continuous protection to Roughan's Point southerly from Profile 15. Structures in the Point of Pines area are partially privately-owned and partially owned by the city of Revere. Structures between Northern Circle and Eliot Circle are owned by the Metropolitan District Commission. The wall and wood bulkhead at Profile 17 are privately-owned. Structures around Roughan's Point and the breakwater on Cherry Island Bar are owned by the Massachusetts Department of Public Works.

43. Protective Structures along Saugus River. - The highway along the Saugus River is protected by a timber pile bulkhead extending from the yacht club to the tip of the point.. The bulkhead has top elevations from 11.0 to 14.0 feet above mean low water, is in a poor state of repair, and its central section is partially buried by a sand dune. A masonry wall, about 225 feet long with top elevations from 13.5 to 14.5 feet above mean low water, has been built in back of the bulkhead near the yacht club. The 250 feet of bulkhead nearest the ocean has

been faced with dumped rock riprap. The highway along the seaward face of the point for approximately 500 feet scuthwesterly from the river is protected by a concrete sea-wall having a top elevation of 15.0 feet above mean low water, which was constructed by a real estate development company about 25 years ago. The southerly half is now buried in a sand dune, while the section adjacent to the river stands 4 to 5 feet above beach elevations. These structures have stabilized the mouth of the Saugus River and protected the upland from serious erosion. The low elevations of these structures have not prevented flooding in the area during storms, and the highway and adjacent yards have often been covered with water, sand, and debris.

44. Protective Structures at South End of Point of Pines. (Figure B-1). - The coast line at the south end of the Point of Pines is protected by heavy riprap for a distance of approximately 850 feet northeast of Northern Circle. This installation is in good condition and, in part, fronts an old timber bulkhead which is rotting out. North of the riprap the coast is protected for approximately 300 feet by a concrete-filled timber crib, with a top elevation of 17.0 feet above mean low water, built in 1933 to replace a previously destroyed wooden bulkhead. The structures do not afford sufficient protection to the area, being overtopped during storms, with the result that the highway is washed out. During the northeast storm of November 28-30, 1945, the road was washed out to depths of 2.5 feet, and heavy granite blocks on top of the riprap were knocked over.

45. Northern Circle Sea-wall. - The Northern Circle sea-wall, constructed in 1904 around the seaward perimeter of a highway traffic circle, is a gravity-type concrete sea-wall having a top elevation of 21.50 feet above mean low water, and a sloping seaward face surmounted by a projecting coping. The sea-wall has been subject to recurring damage, being repaired

in 1923 and 1928, the latter repairs including the jacking back in place of the wall after it had tipped forward. Other repairs have included addition of a toe wall and protective riprap. The wall is in reasonably good condition, but requires repairs. The coping has been broken in places; the construction joints are spalled; and there is a large hole in the face of the wall which exposes the reinforcing steel. The wall has apparently protected the circular road from severe damage, but the beach has eroded.

46. Curb Wall, Profiles 2 to 4. - The seaward edge of the boulevard between Profiles 2 and 4, except in the areas occupied by the stepped seawall and pavilions, is protected by a concrete curb wall having a top elevation of 18.0 feet above mean low water, which is fundamentally a retaining wall for the embankment rather than a seawall. It was constructed in 1940 and 1941 to replace a common highway curb. The beach fronting this wall is generally sandy, with low dunes building up in front of the wall in some areas, and erosion placing the wall in danger of being undermined in other areas. The wall is overtopped by wave spray during storms and minor washouts occur in the adjacent pavements.

47. Stepped Sea-wall Adjacent to Profile 2. (Figure B-1). - The 1500-foot stepped sea-wall which extends southwesterly from a point 300 feet south of Profile 2 was constructed in 1931 to replace a damaged similar structure which was built in 1914. The top of the wall is 17.6 feet above mean low water, the lower step is 11.0 feet above mean low water, and the wall has a total width of 30 feet. It is located at the highwater line and is subject to continuous wave attack, which results in breaking up the lower steps and the curbs over transverse construction joints. At present the lower two steps and toe wall need repairing. Erosion is effected along the front of the wall, except at the southerly end, where the lower step is covered with sand. A row of old piling stands as a wave

breaker in front of the wall at the point of heaviest erosion, and beach elevations are 2-1/2 to 3 feet below the top of the bottom step. Riprap placed around the structure in 1931 has moved slightly seaward in front of the wall and sunk into the beach so as to become practically buried.

48. Pavilions at Oak Island and Revere Streets. - The pavilions at the foot of Oak Island Street and at the foot of Revere Street were constructed in 1904. Each structure is 549 feet long, and their seaward faces are gravity-type concrete seawalls having sloping faces and top elevations of 18.0 feet above mean low water. Both structures are in good condition and have protected the area in back of them.

49. Concrete Bulkhead, Profiles 2 to 4. - In 1916, a bulkhead, consisting of precast concrete slabs and posts, was constructed about 25 feet seaward of the highway. Little is known of its purpose or construction details. Between Revere Street and Oak Island Street, there remains a continuous section, which is generally buried under the beach but is occasionally exposed by storms. Other sections of the bulkhead have been removed. Exposed slabs, which are 6' x 3" x 12" in section, tend to break at their mid-points.

50. Stepped Sea-wall, Profiles 5 to 7. (Figure B-2). - The stepped concrete sea-wall between the Revere Street pavilion and the bathhouse pavilion, constructed in 1916, is approximately 1506 feet long. The top is 18.8 feet above mean low water, and the lowest step, which is 12.5 feet above mean low water, is 26.8 feet in front of the adjacent sidewalk. A sandy beach originally fronted this structure, but since 1932, stones have appeared in large quantities, which wash up onto the steps and at times almost bury them. The wall has suffered considerable damage, partly through the impact of stones, and partly through frost action in spalling and cracking concrete, and requires extensive repairs. The wall has protected the boulevard from serious damage, but waves have washed over it during heavy

storms.

51. Pavilions at Bathhouse and at Profile 12. (Figure B-2). - a. The pavilions at the bathhouse and at Profile 12 were constructed about 1897, and are similar to the pavilions discussed in paragraph 48 above. Two tunnels pass through the bathhouse pavilion and under the road to the bathhouse. The original stepped ramp in front of this pavilion was covered with concrete in 1940, to provide a smooth surface. The pavilion has protected the boulevard from damage, and there is no evidence that it has suffered any damage.

b. The pavilion at Profile 12, shown in Figure B-2, differs from the bathhouse pavilion in that it has no tunnels, and that there is a bastion in front of it. The face of this structure is spalled, but in general the structure is in fair condition, and it has protected the road in back of it. Erosion has lowered beach elevations to points 3 to 4 feet below the top of the foundation for the bastion.

52. Eliot Circle Seawall. (Figure B-3). - The Eliot Circle Seawall, constructed in 1910, is a concrete gravity-type wall 780 feet long, with its mid-section constructed around a 340-foot diameter circle. The wall has a sloping face, projecting coping, and a top elevation of 18.2 feet above mean low water. The wall has not suffered any damage, and has protected adjacent areas from major damage. At the time of construction, the beach was sandy and about 10 feet below the top of the wall. The beach has since built up in front of the wall, and commencing in 1932 it became stony, with a stone ridge tending to reach the top of the wall at the circular section. The ridge has been twice artificially removed from the northerly side of the wall.

53. Wall at Profile 17. (Figure B-3). - The shore at Profile 17 is protected by a dry, granite-block wall, with a top elevation of 19.0 feet above mean low water, located about 250 feet seaward of the Eliot Circle

wall and tied to that wall by an old wooden bulkhead. There is no bulkhead on the east side of the granite-block wall to tie the wall to high land. There are washouts behind both the wooden bulkhead and the unprotected east side of the seawall. The wall in itself is in good condition, and would be sufficient to protect the area if it were properly tied to the upland.

54. Protection at Roughan's Point. (Figure B-3). - a. The northerly side of Roughan's Point, between Profiles 17 and 19, is protected by a stone mound and two 100-foot stone groins. The top of the mound was 18.0 feet above mean low water and of the groins was 3 feet above the beach at time of construction, which was accomplished in two periods - the 225 feet of mound, including one jetty, adjacent to Profile 19 being constructed in 1939, and the balance in 1941. There is a large crescent-shaped stone beach ridge, about 15 feet high, which incloses a pool that is filled and emptied by the tide flowing through the stone mound. Storm tides wash over the mound to add materials to the stone ridge. Accretion of coarse sand and gravel is effected in front of the mound and on both sides of the groins, with the accretion being greatest on the east side of the east groin as the result of normal forces transporting beach materials, and on the west side of the west groin as the result of drainage from the pool. The mound does not afford sufficient protection to the shore, particularly from flooding, and has been displaced adjacent to the granite-block wall.

b. In 1936, a concrete-encased, steel sheet pile seawall was constructed around the extreme point to replace demolished wooden bulkhead. The new seawall extends 1440 feet along the easterly side of the point and 75 feet along the northerly side, and is backed by an earth mound and faced with dumped riprap. The top of the wall is 18.0 feet above mean low water, and the top of the riprap is 5 feet above beach elevations existing at time of

construction. The riprap is extended as a stone jetty at the point, projecting 150 feet north along the principal wall axis and then 140 feet east toward the Cherry Island Bar breakwater. Accretion of sand and gravel occurs along the wall, with the greatest accretion being effected on the east side of the jetty. Thw wall has suffered spalling, and the earth mound in back has been partially washed down, particularly adjacent to the access steps. Wood closures provided for stair wells do not prevent storm waters passing through stair openings. This structure protects the point from direct wave attack which was formerly ruinous to the area, but the area suffers very serious flooding from water passing over and around the wall and through stair wells.

55. Cherry Island Bar Breakwater. - The "L" shaped stone mound breakwater, located about 1200 feet from the shore on Cherry Island Bar, was constructed in 1905, and has a top elevation of 13.0 feet above mean low water. One leg of the structure is 1000 feet long, and the other is 500 feet long. The short leg is located along the axis of a rocky shoal extending to the mainland. The structure suffers severe wave attack and cap stones have been displaced by such action. Its efficiency is indicated by the apparent lack of severe storm damage along the southerly end of Revere Beach, which section is vulnerable to the potentially damaging southeast storms.

VII. PLANS OF PROTECTION

56. Analysis of Principal Features of Problem. - The first beach to occupy a position close to the present Revere Beach, terminated approximately four thousand feet south of the present tip of the Point of Pines. The beach slowly grew northward, becoming wider in the Point of Pines area through the filling of land between successive hooks with natural marsh and artificial deposits. The southern part of the beach remained relatively narrow, there apparently being little material available for building this beach. The natural migration of this beach has been stopped by the construction of various shore protection structures, and by the highway over the normally low area between Revere Street and Northern Circle (Profiles 2 and 4). The highway was constructed by placing 3 to 5 feet of fill over the crest of the then existing beach, the fill being partly hydraulic. Shore protection works along the coast have cut off all onshore sources of beach building materials. Since 1900, the earliest date of profile surveys within the Metropolitan District Commission Reservation, accretion has been effected along the 2,000 feet of beach adjacent to the southerly end, while erosion has been effected along the other 12,000 feet of the reservation. Since 1932, stones have appeared on the beach in great quantities, becoming dense along the southern section which is developed as a major bathing and amusement center, where stones are particularly prejudicial to the recreational use of the beach. Structures along this beach do not suffer great damage during storms, though they are overtopped in severe storms and the adjacent road is washed over. The situation at Revere Beach is thus primarily one of an eroding shore for which there is an inadequate supply of beach building materials, and on the surface of

which fine materials are being replaced with undesirable stones. A secondary problem is the repeated flooding of the northeast end of the beach designated as Point of Pines.

57. Objectives of Study. - The cooperating agency, in initiating the study, stated its objective to be the determination of the best method of preventing further erosion, stabilizing and improving the beaches, and protecting the sea-walls.

58. Improvements Desired by Local Interests. - a. Revere Beach. - The local interests desire that the beach be sanded, and have introduced legislation in the Massachusetts General Court to provide such action. The first bill, House No. 1440 (1945), was introduced in 1945, upon petition by the Mayor of Revere, and resulted in a special report and investigation by the Metropolitan District Commission. This report, House No. 136 (1945), recommends deferment of legislation until the cooperative beach erosion study is completed. In 1946, a second bill, House No. 1360 (1946), was introduced upon petition by the Mayor of Revere, and this bill resulted in a resolve, House No. 1561 (1946), authorizing and directing the Metropolitan District Commission to further investigate the sanding of Revere Beach, and to report to the General Court its recommendations, together with drafts of legislation necessary to carry said recommendations into effect. This resolve was passed by the General Court and approved by the Governor, May 18, 1946, (Chapter 27 - Resolves of 1946).

b. Point of Pines. - The local interests desire a sea-wall or similar protective structure at the Point of Pines between Northern Circle and General Edwards Bridge. Two bills to this effect were introduced in the General Court during 1946, subsequent to the initiation of the beach erosion control study. One bill was House No. 209 (1946), introduced

by a local state representative, and the other was House No. 1297 (1946), introduced upon petition by the Mayor of Revere. These bills resulted in an Act, House No. 1966 (1946), authorizing and directing the Metropolitan District Commission to construct a sea-wall along the shore in the Revere Beach area, from the Northern Circle to the General Edwards Bridge, for the purpose of protecting said shore from erosion by the sea; and to expend sums not exceeding $20,000, one-half of which is to be contributed by the City of Revere. The expenditures are subject to appropriation of funds. The Act was approved by the Governor, June 6, 1946, (Chapter 458 - Acts of 1946). In regard to this legislation, it is to be noted that the original bills directed the work to be done by the State Public Works Department, and that the Commonwealth of Massachusetts does not own land in this area. A highway owned by the City of Revere, generally runs in back of the beach. Elsewhere, the beach is abutted by private property.

59. Protection of Point of Pines. - The scope of the study when initiated, contemplated only sufficient investigation of the Point of Pines area to determine its influence on Revere Beach. When legislative action subsequently assigned the protection of the Point of Pines area to the Metropolitan District Commission, a basic design of such protection was made on the basis of this investigation for Revere Beach.

60. The study of the profiles, storm damage reports, and shore line changes, indicates that the principal problem is that of the low area being flooded by extreme high water during storm periods. The damage known to be directly due to wave attack occurred at the southerly end of the area, between Harrington Avenue, and Delano Avenue, and was also partially due to the low elevations of the land, and the top of the riprap protection. The protective structure required in this area is one which will prevent flooding.

61. The type of structure best suited for the protection of this area is a concrete encased, sheet steel-pile sea-wall, of continuous height, similar in design to the existing wall around Roughan's Point. The success of the Roughan's Point sea-wall, at a more exposed location, provides assurance that a similar wall will provide adequate protection from wave attack. A mound type of structure is considered to be undesirable, because the wide base of such a structure would have to be built entirely on a beach which is generally very narrow, and because of the difficulty in obtaining low permeability.

62. Basic details of the recommended wall are shown on Plate B-5. The wall should extend from high ground at General Edwards Bridge, to the sea-wall at the Northern Circle, and should be located along the seaward edge of the highway. The top elevation of the wall should be maintained at 18.0 feet above mean low water, which elevation is 4.5 to 5.0 feet above the normal high water, and 3 feet above the extreme high water to be expected. This elevation provides protection from high water, and the superimposed storm wave, and is same elevation as the adjacent Revere Beach Reservation Drive, which does not seriously suffer from flooding. The existing riprap protecting the shore adjacent to Northern Circle, should be placed in front of the proposed wall between Northern Circle, and the sand dune near Alden Avenue, as protection against erosion, and to dissipate wave attack. The final design of the wall must consider the access requirements of private property and structures, on the river side of the Rice Road near the General Edwards Bridge. The depth to which the steel sheet piling is driven must be determined on the basis of subsurface investigations, existing beach elevations, and method of anchoring the wall. Between

Northern Circle, and the sand dune, the area in which erosion along the highwater line has occurred, allowance should be made in the detail design of the wall for future erosion of the beach to the elevation of mean low water. In other areas allowance should be made for future erosion of 2 to 3 feet vertically, as protection against any future change in the processes now affecting the beach. These allowances will provide a measure of conservatism in the design of the wall to insure its stability.

63. Access to the beach will be required at several points, and should be provided by steps passing over the top of the wall. Permanent openings in the wall for direct access from the road to the beach would in effect lower the wall height, and the protection afforded against flooding. A basic design of such steps is shown on Plate B-5.

64. Improvement of Revere Beach, Northern Circle to Profile 13. - The principal problem in this area is erosion which has resulted in the loss of fines in the beach material, and the disposition of stone on backshore areas, endangerment of sections of highway through undermining of curb walls, and the loss of extensive areas of dry beach above high water. The stones result from the reworking of existing beach materials, and there is no way that their occurrence can be prevented. The best plan of improving the beach is to bury the stones under sufficient fine materials to prevent their being acted upon by the waves and currents. Artificially placed sand is required to effect the improvement, as there is no littoral drift available for beach building. There is no known source from which suitable artificial fill can be obtained offshore through hydraulic dredging within reasonable pumping or safe working distances. Available information indicates that materials in Lynn Harbor contain great quantities of clay, silt, and muck. Investigation of subsurface conditions in the adjacent

marshes might develop a source of suitable materials. Materials having the same characteristics as the fines on Revere Beach, are obtainable at pits located 12 to 25 miles from the beach, and may be transported overland or by barge to the site.

65. Details of the required artificial beach are shown on Plate B-5, and profiles of the proposed fill in relation with existing and comparative profiles are shown on Plates B-2, B-3, and B-4. The beach is designed to provide a dry beach, generally 125 feet wide above mean high water. The total length of the fill is 13,700 feet. A study of beach slopes that have existed along Revere Beach indicated that a slope of 1 on 13 above mean high water, and 1 on 40 below mean high water, may be expected to be stable. The application of the backshore slope of 1 on 13, to the plots of comparative profiles, showed that the elevation of the fill at the sidewalk line would be generally 18.0 feet above mean low water, an elevation higher than the top of the walls north of Profile 3, excepting the Northern Circle Wall. It was necessary to adopt flatter slopes for the northern part of the beach, in order that the fill would not be above the top of the walls. Between points 500 feet south and 1000 feet north of Profile 3, and in the area north of Profile 2, a backshore slope of 1 on 15 was adopted which provides an elevation of 17.2 feet above mean low water for the fill at the sidewalk line. Between the two above noted areas, a backshore slope of 1 on 16 was adopted, which provides an elevation of 16.8 feet above mean low water for the fill at the sidewalk line. These flatter slopes do not impair the stability of the beach. The plots of the proposed beach slopes show that the low sea-walls will be practically buried in the artificial fill, that the faces of bastions will be protected to elevation above ordinary high water, and that the tunnels

to the Metropolitan District Commission's Bathhouse at Profile 8 will not be affected. Prior to placing the sand fill, all stone deposits should be removed from the surface of stepped sea-walls, and from other areas which will receive less than 3 feet of fill.

66. The artificial beach is to be constructed of material comparable to existing fine beach materials, placed to slopes which have existed in the past, and may be expected to be stable without suffering erosion at a greater rate than has taken place in the past. Erosion in this area has amounted to a loss of 3700 cubic yards of material per year, or 1 cubic yard of material per linear yard of beach per year since 1900. The low rate of erosion, coupled with the varying direction of the littoral drift, indicates that groins are not required to maintain the fill on this beach.

67. The designed beach will provide a suitable dry beach above mean high water for the accommodation of bathers. The wide beach will serve as a wave dissipator for waves attacking the shore, and protect the sea-walls, and pavilions from this attack. The burying of the low sea-walls in the sand fill will eliminate the need for repairing such structures. Where the higher sea-walls and pavilions rise above the new beach elevations, such structures should be repaired as required; the repair work being accomplished under a maintenance program by the local maintenance personnel.

68. Treatment of Revere Beach Profiles 13 to 17. - Shore protection is not required between Profiles 13 and 17. The beach in this area has, during the period of record, experienced continuous accretion. The adjacent highway and land have not experienced severe storm damage. The composition of

the backshore has changed from sand to stone, due to a deposit of stone and shingle which is of sufficient quantity to build a high ridge. The centerline of the ridge tends to align itself with the faces of the Eliot Circle sea-wall, and the pavilion at Profile 12. This ridge has twice been artificially removed, and has rebuilt itself naturally, indicating that it is not feasible to cover the stones with sand. The study indicates that the stones came from beaches, both north and south of the area. It is not considered that structures can be built which will prevent the stone deposits accumulating in this area.

69. The continued growth of the stone ridge presents a beach maintenance problem, in that the ridge can build up to elevations higher than the top of the Eliot Circle sea-wall, and the adjacent highway, and that the seaward slope of the ridge is steep enough to be hazardous to children at times of high water. As noted above, the ridge has twice been removed; the material being hauled away in trucks. At such times, the stones were generally removed to sand levels, an action which is undesirable as the stone ridge forms a natural protective structure against any extreme storm waves reaching the highway. In the future, removal of stones should be limited to only such stones as pile higher than 18.0 feet above mean low water. Bathing should be restricted in the area when the slopes of the ridge create dangerous conditions. A restriction which should not create a hardship on the public, in view of the 13,700-foot long sand beach provided immediately north of the area.

70. Protection of Roughan's Point. - Roughan's Point is not under the jurisdiction of the cooperating agency, and the study of this area was made to develop data on its effect on Revere Beach. The existing protective structures, except for the granite wall and wood bulkhead at Profile 17, are the property of the Massachusetts Department of Public Works. The

Roughan's Point area suffers extensively during storms from flooding. This flooding is in part due to waters passing over and through the stone mound, a condition which may be eliminated by the continuation of the concrete encased sheet-pile sea-wall along the north face of the point. It has also been noted that flooding results from water passing through stair well openings in the concrete encased sheet steel-pile wall in sufficient quantity to severely erode the earth mound backing the wall. This condition may be eliminated by sealing the wells to the full wall height, and providing stairs passing over the wall.

VIII. ECONOMIC ANALYSIS

71. Basis of Analysis. - a. The estimate of first cost has been prepared for the recommended plan of protection and improvement of the present Metropolitan District Commission's Revere Beach Reservation between Northern Circle and Profile 13 near Shirley Avenue. Recommended work on the stone ridge between Profile 13 and Eliot Circle is maintenance and the cost thereof is not estimated. The scope of the study did not permit the development of plans for the protection of the Point of Pines and Roughan's Point areas in sufficient detail for estimating the first cost of the structure.

b. An economic analysis has been made of the recommended plan of improvement and protection for Revere Beach Reservation between Northern Circle and Profile 13, since such work is new work, improving and protecting public property. Analysis was not made of work recommended between Profile 13 and Eliot Circle since such work is maintenance and not qualified for Federal aid in the cost under the provisions of Public Law 727, 79th Congress, 2nd Session.

c. An economic analysis of the recommended protection for the Point of Pines has not been made since sufficient data was not available for cost estimates. The United States is not a landowner in the area and Federal interest is not involved. In the area lying east of the Lynn-Way between Saugus River and Northern Circle, public property has an estimated value of $49,000, comprising land valued at $14,000, sea-walls and bulkheads at $25,000, and shore roads at $10,000. Private property fronting the shore roads has an assessed valuation of $1,209,600. The total tax return on private property is $73,620. Average annual expenditures for repairs of storm damage in the area is $2,500; of which amount $1,000 is spent by the Town of Revere and $1,500 by private interests. The maximum amount of Federal

aid available under Public Law 727, as discussed in paragraph 83, is apparently less than 9% of the total cost of the recommended wall. Local interests believe a wall in this area is justified and have secured legislation enabling its construction.

d. An economic analysis of suggested improvements and protection at Roughan's Point is not made, since their design is not included in the scope of the work. The need of improvements in the area is indicated by the fact that the average annual expenditures for storm repair by the City of Revere is $6000 and by private owners is $4000. Property in the affected area is valued at $1,055,800 for private ownership and $353,000 for public ownership. Public property comprises shore protection structures, land and roads.

72. Estimate of First Cost. (See Appendix III).- The first cost of placing sand fill on Revere Beach between Northern Circle and Shirley Avenue, near Profile 13, is estimated to be $1,012,000.

73. Estimates of Benefits. (See Appendix IV). - a. General. - The benefits to be derived from the recommended improvement of Revere Beach Reservation by the placing of sand fill, are the prevention of direct damages, increase of recreational facilities and increase in property and land values.

b. Average Annual Direct Damages Prevented. - From surveys of storm damages, analysis of storm frequency, and records of the Metropolitan District Commission, it is estimated that the average annual expenditures to repair direct damages over the period of record have been:

Federal	$ 0
Non-Federal Public	16,745
Private	0
	$16,745

The above annual damages prevented, include funds expended in direct repair of damage, the value of the average annual amount of material depleted from the beach, and the annual charges on the amount of money required to repair existing severely damaged structures. Certain of the walls presently require extensive repairs if their exposure to wave attack is to be continued, but the damage to be repaired, however, is principally due to causes other than wave attack, and hence the lost of such repairs are not included in the funds expended in direct repair of damages. The estimated cost of this work is $83,000 with annual charges amounting to $3,900. This expenditure will not be necessary if the proposed plan of placing artificial fill over the beach is adopted.

c. Indirect Damages Prevented. - Indirect losses from storms at Revere Beach are the result of the interruption of traffic and business and the disruption of activities along the Shore Drive. Losses due to interruption of traffic is localized to that experienced by those having residences or definite business on the Drive. There are sufficient roads in the area to detour around the area and during summer months such roads are regularly used for that purpose, since traffic is banned during the afternoon and evening between Eliot Circle and Revere Street. Business losses are to be experienced when conditions prevent the public's access to the various enterprises along the Drive. Sufficient data is not available to permit estimating the monetary value of indirect storm damages. Considering the location, nature and development of the area, and the frequency of recorded storm damage to the road and adjacent property, it is believed that the monetary value of indirect damages is small compared to the direct damages.

d. Increased Earning Power of Property Resulting from Shore Protection. - All property between Northern Circle and Profile 13, the

southerly limit of beach rebuilding, will increase in value as the result of the greater protection from storm attack afforded by the wide, high beach over that afforded by the present miscellany of walls and pavilion, and by the unprotected stretches of shore. Property now owned by the Metropolitan District Commission will be retained in public ownership, hence no return on its increased value can be realized, and no benefit is evaluated. The benefit to privately owned property immediately adjacent to the shore may be evaluated since such property is subject to resale, the evaluation being made in terms of interest at 3.5 percent on the increase in property valuation. Property values have not greatly deteriorated because of the danger of storm damage, since this area has not a record of spectacular storm damage. Conversely, the protection afforded by the placement of sand will not reflect its true worth in the value of the property to the general buying public. The general public will recognize the protection afforded by the wide beach but will place a greater valuation on the recreational benefits than on the protective benefits. Accordingly, it is estimated that property between Northern Circle and Revere Street, which is partially residential and at present less protected than other areas, will increase in value a greater degree than the amusement property between Revere Street and Eliot Circle. As a result of increased protection, it is estimated that property north of Revere Street will increase 10 percent in value and south of Revere Street will increase 5 percent in value, resulting in the following benefits:

a.	Federal	$ 0
b.	Non-Federal Public	8,250
c.	Private	5,580
	Total	$13,830

e. *Recreational Benefits*. - (1) *Revere Beach is the largest* amusement and recreational beach in Massachusetts and serves the entire state as a playground. The improvement of this beach will therefor result in significant benefits, not only to local residents of the Metropolitan area and the state. Present daily attendance at the beach is estimated to be between 150,000 and 200,000 people with holiday peaks reaching the half million mark. This large attendance is probably due in a large degree to the fact that the beach is directly served by the Metropolitan Transit Authority which provides transportation for 10 cents from most parts of the metropolitan area, and in summer transports children for half fare. This situation provides low cost transportation to an ocean beach for city masses who do not possess private cars or who cannot afford other more expensive public and private transportation to more distant beaches. The improvement of the beach will provide approximately twice the area of dry beach above mean high water and eliminate the stone deposits which destroy the value of much of the existing dry beach, with the result that still more people will be attracted to the area and the volume of business of the various beach area enterprises will increase. The valuation of private land and property will increase because of the increased business opportunities and the improved and increased recreational facilities.

(2) The full determination of the monetary value of recreational benefits cannot be made. A dollar and cent valuation cannot be assigned to the benefit derived by a city family from a day spent on the beach. Information on the annual volume of business in the area is not available, but on the basis of reported daily beach attendance, it is estimated that an average expenditure of fifty cents per person would amount to a gross volume of business amounting to $5,000,000 per year.

A partial evaluation has been made to cover benefits represented by the increase in property values and by the increase in use value to beach patrons.

a.	Federal	$ 0
b.	Non-Federal Public	186,490
c.	Private	24,350
	Total	$210,840

74. Federal, Non-Federal Public and Private Interest. - Federal interest in a shore protection project is defined as the benefit secured by the United States as a landowner. Non-Federal public interest is defined as (a) the benefits accruing to a state or political subdivision thereof as a landowner and (b) benefits accruing to the general public. Private interest is defined as the benefit derived by individuals or non-public groups of individuals on account of the ownership of lands and business enterprises. The total interest in a project is the summation of all benefits accruing thereunder.

a. Public Ownership.

(1) Federal. - The federal Government owns no property at Revere Beach.

(2) Non-Federal Public. - Non-Federal publicly owned property along Revere Beach between Northern Circle and Eliot Circle comprises land, sea-walls, pavilions, parks, bathhouse, police station and facilities, sanitary facilities, sidewalks and roads. All public property is owned by the Commonwealth of Massachusetts, Metropolitan District Commission. This public property has the following estimated valuations:

Land	$ 835,000
Sea-walls	500,000
Pavilions	33,000
Buildings	555,000
Roads	490,000
Total	$ 2,413,000

b. Private Ownership. - The assessed valuation of private property and tax income to the City of Revere is as tabulated below. Frontal property is property adjacent to public property. Marginal property is property lying between frontal property and the Narrow Gauge Railroad right-of-way. The tabulation is divided into two areas; Area A, lying between Northern Circle and Revere Street (approximately Profiles 2 to 4), and Area B, lying between Revere Street, Revere Beach Parkway and Ocean Pier (approximately Profiles 4 to 17).

	Assessed Valuation	Annual Tax Return
Area A.		
Frontal Property	$ 856,200	$ 43,840
Marginal Property	29,500	1,510
Area B		
Frontal Property	2,132,600	109,190
Marginal Property	544,900	27,900
Total	$3,563,200	$182,440

Present sales values of private property in these areas are estimated to be 60 percent above assessed valuations. Sales values are:

Area A	
Frontal Property	$1,369,920
Marginal Property	47,200
Area B	
Frontal Property	$3,412,160
Marginal Property	871,840
	$5,701,120

c. Lands, Easements and Rights-of-Way. - The improvement proposed herein is planned for construction on lands now publicly owned, except for a distance of approximately 300 feet northerly of Northern Circle, where it is necessary to place sand fill to terminate the artificial beach properly. The cooperating agency would be required to obtain the necessary land, rights-of-way and easements in this area as the final construction plans indicate to be necessary.

d. Benefits and Interests. - The amount of the interest of one agency in a project is the percentage of that agency's benefits to accrue from the project. On the basis of benefits evaluated in Paragraph 73, the percentage of benefits derived by each agency is as follows:

Agency	Annual Benefits	Per Cent of Interest
a. Federal	$ 0	
b. Non-Federal Public	211,485	87
c. Private	29,930	13
Total	$241,415	100

75. Allocation of Costs. - The basic policy for the allocation of costs is expressed in Public Law 727, 79th Congress, 2nd Session which provides that the Federal Government may contribute a percentage, not to exceed 33-1/3 per cent of the total cost of construction of works for the improvement and protection of shores owned by States, municipalities or

other political subdivisions, excluding costs of necessary lands, easements and rights-of-way. The federal share of the cost of a project thus becomes the percentage of the total interest represented by the Federal interest plus a percentage of the cost of the non-Federal public interest as allowed under the law. Thenon-Federal share of the cost is represented by the non-Federal interest in the total interest less the Federal contribution allowed under the law.

76. Federal interest is shown in paragraph 74 to be zero. Federal participation in the proposed plan of improvement, as determined in paragraph 79, is one-third of the construction cost. The total Federal share of the cost of the proposed plan is thus one-third of the construction cost. The non-Federal share is two-thirds of the construction cost.

77. Annual Charges. (See Appendix III). - The annual carrying charges for the plan of improvement of the Metropolitan District Commission's Revere Beach Reservation will be, it is estimated, $56,810. The annual carrying charges have been based upon interest rates of 3 percent for Federal cost; 3-1/2 per cent for Non-Federal cost and amortization of depreciation and obsolescence over a period of 40 years.

78. Justification of Project. - The average annual carrying charge is estimated to be $56,810. The average annual benefits which have been evaluated are $241,415. The ratio of evaluated benefits to annual costs is 4.2 to 1. Of the benefits evaluated, 87 per cent are public benefits. The complete evaluation of the worth of a beach to a metropolitan area is not readily made, as monetary values are not assignable to the effect of a beach upon the public welfare and health of a city. The easy accessibility of Revere Beach to the entire metropolitan area at low cost on a

publicly operated transportation system creates an asset of great public value. The proposed project of placing 522,000 cubic yards of fill along 13,700 linear feet of shore transforms a presently stony beach into a sandy beach and doubles the width of dry beach above high water in addition to protecting extensive and costly public property from storm attack. While benefits have been evaluated for the increased worth of private property, no monetary value has been assigned to the increased worth of public property due to the improvement because such property will be maintained in public ownership, and the financial gain therefrom will never be realized. An increase in the worth of the public assets is nevertheless experienced due to beach improvements.

79. The proposed plan of improvement will protect public property and will further provide for the encouragement of the healthful recreation of the people. The shore to be protected is owned by the Metropolitan District Commission of the Commonwealth of Massachusetts. The public interest in the protection and improvement of the Revere Beach Reservation has been found to be substantial. The protection and improvement of the publicly-owned beach property and the degree of public interest in such work are considered sufficient to justify the full one-third Federal contribution authorized by the general provisions of Public Law 727, to the first cost of the plan of improvement.

IX. DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

80. Co-ordination With the Cooperating Agency. - a. The results of the study of Revere Beach and the recommended improvements have been discussed with the engineering representatives of the cooperating agency. The representatives approved the plan of improvement.

b. The cooperating agency was advised that the data on the Point of Pines area, obtained within the scope of the study of Revere Beach, was analyzed to determine the type of protective structure required in view of the state legislative action, directing the agency to construct shore protection works at the Point of Pines. The agency was also advised that the scope of the data limited recommendations to basic details of the structure and that further study of the area would be required to prepare a design sufficient for estimating costs, preparing an economic analysis and recommendations pertaining to Federal participation in the project. It was pointed out that the principal problem in the area was flooding and since Public Law 727 does not provide for Federal participation in the construction of shore line structures to prevent flooding, the Federal aid available under the law, as determined from available data, would amount to one-third of the cost of the section of wall protecting the area from wave attack or approximately 400 feet of a 4500-foot wall. The agency was also advised that it was doubtful that further study would develop data that would justify a greater amount of Federal aid.

81. The cooperating agency has been advised of requirements as set forth in Paragraphs 99 and 100, which must be met by local authorities in the prosecution of projects in which the Federal Government participates. The cooperating agency has already accepted these

conditions as applied to the improvement at Winthrop Beach recommended under the cooperative study and contained in the report on Winthrop Beach, published in House Document No. 764, 80th Congress, 2nd Session.

82. Discussion of Plan for Point of Pines. - Geological history shows that this point is the result of the growth of a succession of hooked spits which grew both northward and westward with the valleys between hooks being filled with marsh deposits and artificial fill. Recent history indicates that the shore lines have been stable, with accretion being experienced along the Saugus River and the northerly part of the seaward beach where a sand dune has been built. Along the southerly part of the seaward beach, erosion has been effected at the high water line and accretion at the low water line, and it is only in this area that storm wave damage has been experienced. Other areas experience flooding during storm periods from the extreme high waters which build up in Broad Sound, Lynn Harbor and Saugus River. The area is naturally low and elevations along Rice Road are in places just above normal high water. Miscellaneous walls, bulkheads and rip-rap have been constructed along the shore but they are too low to protect the area from flooding. As discussed in Paragraph 59, the design of protection for this area was not contemplated in the initiating of the study. Analysis of the data obtained for the study of Revere Beach and the present situation at the Point of Pines leads to the conclusion that the best protection to be afforded the area from flooding and from the limited wave attack experienced at the southern part of the point is a concrete-encased steel sheet pile wall having a top elevation of 18.0 feet above mean low water and extending from the General Edwards Bridge to Northern Circle.

83. The data available for the added study of the Point of Pines was sufficient only for the design of basic sections of the sea-wall. Consideration of the extent of the area subject to wave attack indicates that only 1200 feet of the recommended 4500-foot long sea-wall would be used to protect the shore from wave and current attack, and under Public Law 727, the maximum possible Federal aid in constructing the sea-wall would be limited to one-third of the cost of the 1200-foot section or less than 9 per cent of the total cost of the entire wall. In order to obtain the maximum Federal aid, the entire shore would have to be publically owned, a condition not presently existing.

84. Discussion of Plan for Revere Beach Reservation. - The early history of Revere Beach indicates that the initial beach was naturally built of materials obtained in the area south of Oak Island. The limited amount of available materials resulted in the northerly part of the beach being low in elevation and, except in the Point of Pines area, narrow. The low land was partially filled by artificial methods, particularly the area between Revere Street and Northern Circle where 3 to 5 feet of hydraulic fill was placed during highway construction in 1905.

85. Recent history of Revere Beach within the limits of the Metropolitan District Commission's Reservation has been one of erosion north of Profile 13 and accretion south of that profile. Within the erosion area, a deposit of stones has been left on the back shore creating an unsatisfactory beach for recreational purposes. Within the accretion area, a stone ridge has been built upon a formerly sandy beach. The volume of erosion exceeds the volume of accretion, indicating that fines eroded from the northerly part of the beach are being

transported to some area other than that south of Profile 13. The fines have undoubtedly been used in the construction of the sand dune at the north end of the beach, adjacent to Profile 1, which has buried 250 feet of a sea-wall.

86. The configuration of the coast line is such that Revere Beach is protected from direct attack from the dominant storms and winds, with the result that waves approaching the shore are refracted waves and a condition is created under which the direction of littoral drift is reversed from north to south at varying times. The reversal of drift is evidenced by the geological growth of the beach, the location of the sand dune and the location of stone beach ridges.

87. Revere Beach Reservation has not suffered severe storm damages, though the highway is occasionally washed over. Hence, a continuous shore protective structure has never been constructed along the beach. Several sections of the shore are protected by sea-walls and pavilions having an aggregate length of approximately 6200 feet. The remaining 8250 feet of reservation shore-line is without protection except for 5500 feet of concrete curb wall which is fundamentally a retaining wall for the highway. The only serious damage experienced by shore line structures has occurred at the northern end of the beach, where the beach is the narrowest. Here the Northern Circle sea-wall has been undermined and repaired and the stepped sea-wall has been reconstructed. The continual erosion of the beach will endanger all structures and in certain locations the curb wall and adjacent highway are in imminent danger of being washed out. The shore line structures at present are in various stages of disrepair, certain structures requiring considerable work to place them in proper condition.

88. Revere Beach is the largest and most popular recreational beach in the Metropolitan Boston area. Local interests are seeking legislative action to improve the beach artificially since stone deposits on the back shore are prejudicial to recreational use of the beach and the erosion of this beach has resulted in considerable loss of dry area above the mean high water line.

89. The improvement of the beach, under present conditions in relation to source of materials and the rate of supply and loss, can be obtained only through the artificial placement of sand on the beach between Northern Circle and Profile 13. The designed artificial beach will arrest the erosion which now deposits stones on the back shore and endangers shore line structures; will protect existing structures by burying them in sand to elevations above extreme high waters, and eliminate the need of making repairs presently required if the structures are left exposed; will provide a beach 125 feet wide at mean high water which will accomodate beach patrons and also serve as a dissipator for waves attacking the shore line; and will eliminate the objectionable stone deposits which now spoil the recreational value of the beach. All stone which is deposited on sea-walls and in other locations where the fill will be less than three feet deep should be removed prior to placing the artificial fill. With proper maintenance and periodic replenishment of artificial fill it is to be expected that Revere Beach will be stabilized in a position which will afford adequate protection for the shore line structures, highway, and adjacent property, and will provide a suitable and desirable beach for recreational purposes.

90. It is not considered that it is necessary to construct groins to maintain the artificial beach since the littoral drift periodically reverses its direction along the shore and the past annual rate of erosion has been but one cubic yard of material per linear yard of beach. The comparative profiles, periodically surveyed since 1900, should be resurveyed annually as a means of determining the processes affecting the fill and a guide to the future maintenance and replenishment of the fill.

91. In the area south of Profile 13, the analysis of present conditions indicates that the continued growth of the stone beach ridge cannot be stopped. The placing of artificial fill in the immediate northerly area will arrest the movement of the stones from that area and it is to be expected that some sand may be moved from that area. The stone ridge serving as a natural protective structure should be allowed to accumulate and should not be artificially removed as it has been in the past.

92. The total cost of the proposed plan of improvement for the Revere Beach Reservation by artificial placement of sand fill is $1,012,000. The shore to be protected and improved is owned by the Metropolitan District Commission of the Commonwealth of Massachusetts and public interest in protecting and improving the beach has been found to be substantial. The protection and improvement of this publicly-owned beach and the degree of public interest therein are sufficient to justify the full one-third Federal contribution toward the first cost of an economically justified project, as authorized by the general provisions of Public Law 727, 79th Congress, 2nd Session. The estimated Federal contribution toward the proposed plan of improvement

would be $337,300.

93. The annual cost of the proposed plan of protection and improvement of the shore of the Revere Beach Reservation is estimated at $56,810. Partially evaluated benefits to be derived therefrom amount to $241,415. The ratio of evaluated benefits to annual costs is 4.2 to 1. Benefits, including the protection and preservation of public property and the development and improvement of recreational facilities, as discussed in Paragraphs 73 and 78 are found to be of sufficient value to justify the cost of the project. The benefits to be realized from the project have been determined to be 87% public and 13% private.

94. Conclusions. - The Division Engineer concludes that the best plan for preventing further erosion, stabilizing and improving the beach and protecting sea-walls and other public property at Revere Beach consists of the following items, details of which are shown on Plate B-5:

a. In the Point of Pines area, between General Edwards Bridge over the Saugus River and Northern Circle sea-wall, the construction of a concrete encased steel sheet pile sea-wall;

b. In the Metropolitan District Commission's Revere Beach Reservation between Northern Circle and Profile 13, a point near Shirley Street, the improvement of the beach with an artificial supply of sand; and

c. Between Profile 13 and Eliot Circle the maintenance of the natural stone ridge to the elevation of the adjacent highway.

The Division Engineer concludes that the above construction is warranted.

95. The recommended plan of protection for the Point of Pines area is a basic plan developed as an aid to the cooperating agency, which has been charged by legislative action since initiation of this study, with the construction of protective works in the area. Further study of the area is required to determine completely the cost of the project and its eligibility for Federal aid under the provisions of Public Law 727. On the basis of available data, the Division Engineer is of the opinion that maximum possible Federal aid under existing law would amount to less than 9 percent of the total cost of the structure.

96. That part of recommended plan of improvement and protection of the Revere Beach Reservation which consists of artificially building up the beach between Northern Circle and Profile 13, is considered to be new construction and is primarily for the protection of publicly-owned shores. It, therefore, meets the requirements for Federal participation in the first cost of construction of works for the improvement and protection of the shore. The nature and amount of public benefits are considered to be sufficient to warrant the maximum one-third participation by the United States in the first cost of the proposed new construction, as permitted by Public Law No. 727, 79th Congress, 2nd Session. The balance of the proposed work for Revere Beach Reservation, involving periodic leveling of the stone ridge, is strictly maintenance work, and as such is not eligible for participation by the United States.

97. In the study of the effect of Roughan's Point upon Revere Beach Reservation it was noted that the residential area in the rear of existing shore protection structures is subject to severe flooding. It is considered that local authorities should alleviate the flooding

of the area by extending the sea-wall to Eliot Circle and by modifying stairwells in the existing wall so that openings in the wall are permanently closed to the full height of the wall.

98. Recommendations. - It is recommended that the Commonwealth of Massachusetts adopt a project for the protection and improvement of Revere Beach to the extent of:

a. Constructing a concrete-encased steel sheet-pile sea-wall having a top elevation of 18.0 feet above mean low water in the Point of Pines area between the General Edwards Bridge and Northern Circle, a distance of 4500 feet.

b. Improving Revere Beach Reservation by placing on the beach 522,000 cubic yards of sand fill between Northern Circle and Profile 13 near Shirley Avenue, a distance of about 13,700 feet, to provide a backshore elevation of 18.0 feet above mean low water, except at the northern end of the beach where local conditions require backshore elevation between 16.8 and 17.3 feet above mean low water, all at an estimated cost of $1,012,000 and $10,630 for maintenance.

c. At the southerly end of Revere Beach Reservation, between Profile 13, near Shirley Avenue, and Eliot Circle, allowing the stone ridge to remain undisturbed except for periodic leveling of its top when it reaches an elevation higher than that of the adjacent road.

d. Prevention of flooding of residential areas at Roughan's Point by sealing openings in the existing sea-wall and extending its sea-wall to Eliot Circle.

99. It is recommended that the United States adopt a project for the protection and improvement of the shore of Revere Beach Reservation between Northern Circle and a point near Shirley Avenue by

authorizing participation through the contribution of Federal funds in an amount equal to one-third of the first cost of the construction of the project. The project consists of the work described in Sub-paragraph 98-b, and its cost to the United States is estimated to be $337,300. Contribution of Federal funds should be made contingent upon approval by the Chief of Engineers of the detailed construction plans and specifications and the arrangements for the prosecution of the new work prior to its commencement.

100. It is further recommended that the contribution of Federal funds should also be contingent upon agreement with the Commonwealth of Massachusetts providing that the Commonwealth will:

a. Maintain and repair the work as may be required to serve the intended purpose;

b. Provide free of cost to the United States all lands, easements, and rights-of-way necessary for the initial work and subsequent maintenance;

c. Hold and save the United States free from claims for damages connected with or resulting from the work.

101. The adoption of a Federal Project in the Point of Pines area is not recommended without further study of the area.

JAMES H. STRATTON
Colonel, Corps of Engineers
Division Engineer

18 Inclosures
11 Plates
3 Figures
4 Appendices

REVERE BEACH

Appendices I - IV

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APPENDIX I

EXISTING PROTECTIVE STRUCTURES AT REVERE BEACH

1. General. - The coast line of Revere Beach, from the Point of Pines to Roughan's Point, is lined with a discontinuous series of structures, only part of which were constructed for the express purpose of shore protection. This appendix describes the structures, as they occur, from the Point of Pines to Roughan's Point and their relation to beach conditions. Locations and sections of structures are shown on Plate B-1, and pictures of the principal protective structures are shown on Figures B-1 to B-3, inclusive.

2. Protective Structures at Mouth of Saugus River, Point of Pines. - The first shore protection constructed in the Point of Pines area was the concrete wall extending from the river southwesterly along the ocean beach for a distance of approximately 500 feet. This wall was constructed about 25 years ago by a real estate development company. The northerly half of the wall stands 4 to 5 feet above the beach and the remainder is buried in a sand dune which has built up since the wall was constructed. The concrete wall is in good condition. The shore of the Saugus River for approximately 250 feet adjacent to the concrete wall is protected by heavy riprap which was placed by the City of Revere. A bulkhead, constructed of closely driven timber piles, stands behind and extends approximately 300 feet beyond the riprap, and is in a poor state of repair, with some of the piles missing. The bulkhead and riprap were constructed some time after the concrete wall. These structures have served to stabilize the mouth of the Saugus River. There is some flooding of the road

behind the wall and bulkhead at high storm water and extensive flooding beyond the bulkhead of the lowlands nearer the main highway. The beach along the Saugus River is generally firm sand containing a moderate amount of stone. The backshore area fronting the bulkhead is stony, while southwest of the bulkhead it is of soft sand with a belt of stones at the base of a sand dune. The beach at the extreme point is stony, and old piles protrude above the beach, apparently the remains of a wharf shown on old plans dated 1901. The beach on the ocean side of the point is sand. In front of the concrete wall the backshore area is soft sand, building up to the sand dune which buries the southerly end of the wall and extends to about the midpoint of the Point of Pines Area. The foreshore beach is hard-packed with a very flat slope.

3. Protective Structures at Southerly End of Point of Pines (Figure B-1). - Subsequent to the development of the Point of Pines Area, 35 years ago, private interests constructed a wood bulkhead along the south end of Rice Avenue. This bulkhead is rotting and is partially armored by riprap which extends beyond the end of Rice Avenue to the Northern Circle, having a total length of approximately 850 feet. The riprap, which averages 2 cubic yards in size, is in good condition and was partially placed by the City of Revere. In January 1933, the northerly 300 feet of bulkhead which is not armored by riprap was destroyed and was later replaced by a concrete filled, timber crib. A dry wall of granite blocks, similar to sidewalk curbings, was also built at the top of the riprap at the south end of Rice Avenue. These structures do not afford sufficient protection to the area. While normal high water is at the base of the riprap, high storm waters wash up over it and wash out the road. The storm of

November 28-30, 1945 washed out Rice Avenue for depths up to 2-1/2 feet and demolished the dry granite block wall. The beach in this area is sand, ranging from soft on the backshore to hard-packed on the foreshore.

4. Metropolitan District Commission Structures. - The several types of shore protection structures between Northern Circle, adjacent to Profile 2 and Eliot Circle, at Profile 16, are owned by the Metropolitan District Commission and were generally erected by the Commission or its predecessor, the Metropolitan Parks Commission, which acquired the beach as a public reservation in 1895. Prior to this time there were no protective structures along the shore. A railroad ran along the crest of the beach at about the location of the present highway. This railroad, constructed about 1876, was partially supported on wood trestles. The railroad was later relocated inland to allow development of the reservation. The construction of the reservation included the placing of hydraulic fill between Profiles 2 and 4, which, though records are not available, is believed to have been taken from the ocean.

5. Concrete Bulkhead, Profiles 2 - 4. - In 1916 a concrete bulkhead was constructed along the beach about 25 feet seaward of the highway. There is no record of its total length but it is known to have extended from Revere Street to Oak Island Street, and there are also evidences of it adjacent to the ends of the stepped sea-wall near Profile 2. The bulkhead consisted of reinforced concrete posts, 9 inches by 9-1/2 inches in section, and reinforced slabs, 3 inches by 12 inches in section, set in slots cast in the wide sides of the posts. The posts were set 6 feet on centers. Records are not available to show

the length of the posts, the depth to which the slabs were placed, or beach condition at time of erection. The slabs tend to break in the middle and where the slabs and posts project above the beach, they are removed. Sections still remaining in place are generally buried in the beach between Revere Street and Oak Island. The storms of November 28-30, 1945 and March 2, 1947 exposed considerable lengths of these sections, but they have since been reburied by beach materials.

6. Northern Circle Sea-wall.- The Northern Circle sea-wall was constructed in 1904 around the seaward perimeter of a highway traffic circle. The radius of the circle is 141 feet and the wall extends 190 degrees around the circle. The wall is a gravity-type concrete wall with reinforcing steel in its face and coping, the coping being a separate casting to that of the wall. The face of the wall has a batter of 1 1/2 inches to 1 foot. The top of the coping is at elevation 21.5 above mean low water, the base of the wall is at elevation 7.0. The wall above elevation 18.0 is 2 feet wide and below that elevation the wall uniformly increases in width to 7.0 feet at its base. This sea-wall has been subjected to recurring damage from wave action. Repairs were required in 1923 and again in 1928 when the wall was jacked back in place and a toe wall added after it had been undermined and was tipping over. Riprap was placed around the base of the wall. At present the coping is broken in places, the edges of construction joints are spalled and there is one large hole in the face of the wall which exposes the reinforcing steel. The wall has protected the circular road from severe damage, but the beach fronting it has eroded. The beach is hard-packed sand with a deposit of stone in the upper tidal ranges.

7. Curb Wall, Profile 2 Area. - Shore protection has not been provided between the Northern Circle Sea-wall and the stepped sea-wall. Original construction in the area included a highway curb along the seaward edge of the promenade. Drains from highway catch basins were extended 30 to 40 feet across the beach at a minimum depth of 3 feet below beach level to leaching basins. The curb was replaced in 1940 and 1941 with a concrete curb wall which acts as a retaining wall for the highway. This wall is 5 feet high, 12 inches wide at top and 18 inches wide at bottom. The wall projected 1 foot above the level of the promenade (now used for a parking area) and was fronted by a bank of beach material which rose to the level of the promenade. The material in front of the wall has been generally washed away and the wall is in danger of being undermined.

8. Stepped Sea-wall Adjacent to Profile 2. (Figure B-1). - The stepped sea-wall which extends southwesterly from a point 300 feet south of Profile 2 was originally constructed in 1914, and has a length of 1500 feet. Below elevation 10.0 feet above mean low water, there was a sloped-face gravity-type toe wall having a top width of 28 inches and a bottom width of 43 inches. The elevation of the bottom varied from 5 to 7 feet above mean low water. The toe wall was cast over a 10 feet cut-off wall constructed of 3-inch tongue and grooved boards. Between elevation 10 and elevation 18 the wall was a stepped, reinforced concrete slab supported on integral beams and stringers. There were nine steps above the top of the toe wall, and the slab sloped back for a distance of 30 feet from the face of the toe wall. The slabs were cast in 21-foot sections, the joint at each section being capped by a concrete curb. This original wall was damaged and in 1931 was rebuilt to its present lines. The rebuilding comprised the construction

of new end walls, 16 inches thick and generally 12 inches higher than the steps; the armoring of the exposed face of the toe wall section and stepped slab section with 12 inches of reinforced concrete; the construction of concrete piers and girders to support the center of the steps and the construction of a wall to support the back edge of the stepped slab. Provision was also made to drain highway catch basin outfalls through scuppers in the face of the stepped slab section. The wall, being constructed at the mean high water line, is subject to continuous wave action which results in the spalling and breaking of the lower concrete steps and the lower part of the curb over the expansion joints. Erosion is generally taking place in front of the wall, being the heaviest in the central portion where a row of old piling stands in front of the wall. The beach elevation is 2-1/2 to 3 feet below the top of the bottom step at the point of greatest erosion. Accretion, however, is in effect at the southern end of the wall, and there the bottom step is covered with sand. The wall has prevented serious damage to the area, though the road has suffered flooding and minor washouts. At the time of rebuilding in 1931, riprap was placed in front of the wall. This riprap has since generally sunk or moved forward of the toe of the wall. Some riprap was also placed on either side of wall.

9. Curb Wall Between Stepped Sea-wall and Revere Street Pavilion. - With the exception of the pavilions at the foot of Oak Island Street and Revere Street there is no shore protection between the south end of the stepped sea-wall near Profile 3 and the stepped sea-wall at Profile 4. The beach in this section is bordered by a continuous parking area which was originally a promenade and along which there was originally a standard concrete curb. Highway catch basin drains were constructed

under the beach as in areas north of the stepped sea-wall. In 1940 and 1941 the curb was replaced with a concrete curb wall which acts as a retaining wall as described in Paragraph 7 above. There are four concrete ramps leading to the beach at intervals along the retaining wall, which were originally constructed prior to 1916, and have been rebuilt at various times because of damage, the dates of the last reconstructions being 1937 and 1940. The ramp at Profile 3 is presently totally destroyed and the other ramps are in reasonably good condition. A brick sanitary building was constructed on the backshore area about 300 feet north of Profile 3 in 1937. There is an unprotected embankment around this building which apparently suffers a minor amount of erosion. The beach in front of the concrete retaining wall is generally sandy varying from soft sands in backshore areas to hard-packed sand in foreshore areas. The sand piles up against the wall in varying amounts to form low dunes in some areas, but is subject to erosion under storm waves. Stone cusps occur on backshore areas varying from slight traces to relatively dense deposits, their position varying from the high water line to the sea-wall though generally located near the highwater line. The retaining wall, though in danger of being undermined in places, has prevented any major washouts in the road since it was constructed. Storm waves wash over the wall onto the road leaving debris on the road and minor washouts in pavements.

10. Pavilions at Oak Island Street and Revere Street. - The pavilions at the foot of Oak Island Street and Revere Street were constructed in 1904. These structures are each 549 feet long and serve as shelters. The Revere Street pavilion contains underground toilet

facilities. The seaward wall of the pavilions are constructed as concrete gravity-type sea-walls with a top width of 2 feet, a bottom width of 7-1/2 feet and a batter of 1-1/2 inches to 12 inches on the exposed face. The top of the wall is at elevation 23.0 above mean low water and the base at elevation 8.0 above mean low water. The face of the wall was picked or chipped for architectural effect and the steps and coping were made of marble chip aggregate. Both structures are in good condition, have not suffered any great damage and have protected the area behind them from damage. The beach in front of the pavilions is hard-packed sand with stone cusps occurring in front of the Revere Street Pavilion.

11. Stepped Sea-wall, Profiles 5 to 7 (Figure B-2). - The stepped sea-wall between the Revere Street and Bathhouse Pavilions is about 1511 feet long and was constructed in 1916. This wall is similar in detail to the stepped wall near Profile 2 except that four bastions are provided at intervals along its length. The toe wall has a batter of 1-1/2 inches on 12 inches and varies from 2 to 2-1/2 feet in width, with bottom elevation of 3.0 feet above mean low water and a top elevation of 12.5 feet above mean low water. There are 7 steps in the stepped section of the wall and its top is 18.8 feet above mean low water at a distance of 26 feet 10 inches behind the toe wall. A discontinuous curbing runs along the top step. The bastions, 39.5 feet long and projecting 14 feet seaward from the sidewalk, are formed by a gravity-type concrete wall having a top width of 1 foot 10 inches, bottom width of 3 feet 6 inches, and a top elevation of 19.8 feet above mean low water. This sea-wall originally faced a sandy beach and maintenance crews were employed to sweep the steps clean of sand. The stones working northerly

along the beach, since Roughan's Point commenced to erode in 1932, wash up onto the steps and at times almost completely cover them. The stones lie along the wall at all periods of the year. The wall has suffered considerable damage from spalling and cracking of concrete, being partly due to freezing of water in cracks in the surface of the concrete. The curb along the top of the wall is partly broken down. The wall has protected the adjacent shore from serious damage, but high water has washed over the wall onto the adjacent road. The beach is generally covered with stones above highwater elevation. Below high water elevation, the beach is hard-packed sand.

12. Bathhouse Pavilion. - The Pavilion at the bathhouse in Profile 8 area was constructed around 1897. Plans of the structure are not available. It is constructed of concrete and is similar to the pavilion at Profile 4, except that there are two tunnels, passing under the pavilion from the beach to the bathhouse, located across the highway. A concrete apron, having a stepped surface was constructed in front of the pavilion wall. These steps were damaged and were covered with concrete in 1940 to form a smooth surfaced ramp. The structure is not known to have suffered any serious damage beyond that noted for the original stepped ramp. The beach fronting the ramp is hard-packed sand and has suffered slight erosion.

13. Profile 9 to 12 Area. - There are no shore protection works between the pavilions at Profiles 8 and 12. A concrete curb, 7 inches by 18 inches in section, was constructed about 1910 along the edge of the sidewalk. Stones, which pile against the seaward face of the curb, and build up to its top, extend seaward to about the high water line, below which the beach is hard-packed sand.

14. Pavilion at Profile 12 (Figure B-2). - The Pavilion at Profile 12 was constructed about 1897. Details of its construction are not available. It is similar to the pavilion at Profile 4 except that a bastion was constructed in the central part of the pavilion in lieu of the flight of steps leading to the beach. The pavilion is in fair condition. Erosion has been effected in front and around the bastion and the beach elevation is between 3 and 4 feet below the top of the foundation wall. Stones pile against the base of the pavilion. The foreshore area fronting this structure is hard-packed sand. There is no record of damage occurring in the area behind the pavilion.

15. Profile 13 to 15 Area (Figure B-3). - There are no shore protection works in the area. A sanitary building was constructed about 1900 at Profile 13. It was torn down and replaced with the present sanitary building in 1938. Both buildings were constructed without protective works. Accretion is generally effected in this area. In the backshore near Profile 13, the accretion is of sand, but about 350 feet south of Profile 13, it becomes stony and extends in that condition to Profile 17 with the stones piling up as a high beach ridge. The ridge has twice been removed by the Commission, the latest time being in the spring of 1946 when all stone between Profiles 16 and 13 was removed to the natural beach elevation. This ridge is rebuilding as shown in Figure B-3. The foreshore area is hard-packed sand.

16. Eliot Circle Sea-wall. (Figure B-3). - The Eliot Circle sea-wall constructed in 1910, is a gravity-type, concrete wall 780 feet long with its central section extending 230 feet around the perimeter of a circle 340 feet in diameter. The sea-wall has a top elevation of 18.2 feet above mean low water and a base elevation varying from 6.2

to 3.2 feet above mean low water, varies in thickness from 2 feet at the top to 6 feet at the bottom and has a batter of 1-1/2 to 12 inches on its face. A toe wall, 18 inches wide, extends 4 feet below the base of the sea-wall. A coping cast separate from the body of the wall, projects 5 inches in front of the wall. This structure has not suffered any serious damage. Prior to the beginning of the movement of stone from Roughan's Point in 1932, the beach was sandy and about 10 feet below the top of the wall. Since that time, stone has built up along the face of the wall, reaching the top of the wall in the curved section and elevations four to five feet below the top of the wall in other sections. The stones against the northerly half of the wall were removed for highway fill during the spring of 1946, returning the beach to almost its original level. At that time, fine sand was deposited behind a short section of the old beach ridge which was left extending northerly from the center of circular wall section. The ridge has since redeveloped. The beach ridge south of the circular section has not been touched and the backshore area is entirely stones. The foreshore area north of the circular wall is hard-packed sand, while south of the wall it is boulder strewn. The sea-wall has prevented any serious damage to the area behind it.

17. Profiles 17 to 19 Area (Figure B-3). - a. A privately owned masonry wall was constructed at Profile 17 prior to 1894. The wall was built of granite blocks about 3 feet by 4 feet by 6 feet in size and was laid up as a dry wall with its top 19 feet above mean low water. The wall has substantially protected the land in back of it though there is erosion of fill materials behind its easterly end, where there is no bulkhead between the east end of the wall and the upland.

Riprap which was placed adjacent to its easterly end in 1941 has been washed down. The wall stands about 250 feet seaward of the Eliot Circle Wall and is connected to it with a wood bulkhead which is in a state of total disrepair and allows the backfill to work through it. A wooden pier, about 750 feet long extends from the granite wall. This pier is about as old as the wall and has had no apparent effect upon the beach.

b. Between the end of the granite wall at Profile 17 and the extreme tip of Roughan's Point at Profile 19, the coast is protected by a stone mound which has been constructed at three different periods. The tip is further protected by a concrete sea-wall which extends 1440 feet southerly along the seaward face of the point to the "Missing Link" section of Winthrop Parkway and 75 feet along the northerly side of the point toward Revere. The concrete wall was constructed and the first riprap was placed in 1936 by the Massachusetts Department of Public Works. The sea-wall comprises a core of steel sheet piling encased in 6-inches of concrete, with the seaward face being provided with a 12 inch wide curved lip for returning wave wash to the beach. The top of the wall is at elevation 22.0 feet above mean low water except at the access steps leading to the beach. Wood enclosures are provided for the stairways during the winter. The concrete encasement was extended to a depth of 2 feet below the existing ground line. The top of the steel piling is at elevation 21.5 feet above mean low water and vary from 34 to 42 feet in length except for 52 feet of the return wall where they are 20 to 30 feet long. Earth fill was placed in back of the wall to elevations 18.0 above mean low water, the fill having a slope of 1-1/2 on 1 on the landward face and meeting existing ground level about 25 feet from the wall. The seaward base of the wall was

protected by heavy stone riprap placed to an elevation of 5 feet above the beach level with a top width of 2 feet and a slope of 2 on 1. At the northerly end of the wall, the riprap was extended as a jetty to a point 150 feet north of the end of the wall and thence 140 feet easterly at right angles to the principal axis of the wall.

c. In 1939, the Massachusetts Public Works Department extended the riprap as a stone mound for 225 feet along the west side of Roughan's Point toward Revere Beach. The mound had a top width of 3 feet at elevation 18.0 feet above mean low water, a seaward slope of 1-3/4 to 1 and a landward slope of 1 to 1. A 100-foot groin having a stone core with a heavy stone shell was provided at the westerly end of the mound. The groin had a top width of 3 feet, side slopes of 1 to 1 on the landward side and 1-3/4 to 1 on the seaward side and a top elevation 3 feet above existing beach. In 1941 the stone mound was extended 265 feet to the granite wall at Profile 17, and a second 100-foot groin was constructed about 120 feet east of the granite wall. Both the riprap and groin are of the same section as those constructed in 1939 except both slopes of the mound are 1-1/2 to 1. Between the granite wall at Profile 17 and the concrete wall at Profile 19, the mound has not been sufficient to protect the area from wave action and 20 feet of the riprap immediately adjacent to the granite wall has been displaced. There is a crescent shaped stone beach ridge in back of the mound which has a crest height of about 15 feet above mean low water, extends from a point 15 feet west of the end of the granite wall to a point about 150 feet from the end of the concrete wall, and is about 50 feet in back of the mound at its midpoint. A low area between the mound and the ridge is flooded at high water and channels on the foreshore indicate that water flows from the area during low water. While the ridge probably existed before

the construction of the mound, it is believed that it is still growing. Accretion is being effected immediately in front of the mound and at the groins, but the accretion appears greatest on the east side of the easterly groin and on the west side of the westerly groin. The beach is stony and boulder strewn. The concrete sea-wall at Roughan's Point has afforded the area protection from direct wave action during the storms, but has not protected the area from flooding during storms. The entire area was flooded during the storm of November 28-30, 1945 and residents of the area were required to evacuate their homes. After storms in November of 1947, it was noted that storm waters had poured through all stair wells, even though the wood closures were in place. Very severe erosion took place at the embankment directly in back of the wells. Waters pouring through these openings contribute considerably to the frequent floodings of the area. The wall has suffered some damage from spalling on its face. Accretion is taking place along the face of the wall at the tip of the point where the riprap is partially buried with stone. A stone ridge generally covers that section of riprap which extends as a jetty from the corner in the wall.

18. Cherry Island Bar Breakwater. - The Cherry Island Bar Breakwater was constructed in 1905 on the remains of an island that had been eroded to about mean low water elevation. The structure is located about 1200 feet offshore and is L-shaped. The short leg, about 500 feet long, is located on Profile 20 and is in line with the westerly side of Roughan's Point. The long leg is about 1000 feet long and extends northward from the outer end of the short leg. The structure is constructed as a mound of heavy stone, having side slopes of 1 on 1-1/2 and a top elevation of 13.0 feet above mean low water. The top

of the long leg is 8 feet wide and the top of the short leg is 5 feet wide. The breakwater is subject to storm damage and many of its cap stones have been displaced, partly by storms in the latter part of 1945. Since southeasterly storms are potentially the most dangerous to Revere Beach, this breakwater affords considerable protection to the southerly end of the beach and its effectiveness is indicated by the apparent lack of severe storm damage in this section. There is a stony, boulder strewn shoal area between the breakwater and the mainland which is the remains of the eroded island.

APPENDIX II

COMPOSITION OF REVERE BEACH

1. General. - The present composition of Revere Beach may be summarized as a hard-packed sandy foreshore and a stone to sandy backshore. The shore of Roughan's Point at the south end of Revere Beach is stony and boulder-strewn. At the south end of Revere Beach the backshore area is normally covered with a high stone beach ridge which is periodically removed by man. The stones continue to occur northward along the entire beach, varying in density and distribution until the Point of Pines area is reached where the backshore becomes entirely sandy and a large sand dune is building up. The stones are particularly dense in the area utilized for amusement purposes, Profiles 4 to 12, and at times cover the stepped sea-wall near Profile 4. The density of stone deposits varies with the seasons and there are considerable more stones present on the beach in winter months than in summer months. Typical pictures of the beach in July and March 1946 are shown in Figures B-1 to B-3.

2. Summer Beach Conditions. - The following notes indicate typical summer beach conditions between Saugus River and Roughan's Point. The notes were made in July 1946 with the exception of those for Profile 17, which were made in May 1946.

a. Profiles 26-28. - A low sand dune extends westerly from bulkhead ending near Profile 27. Stones pile along the base of the sand dune and bulkhead. The beach is hard-packed sand containing a moderate amount of stone, becoming stony at the extreme point at Profile 25. There is soft sand in the backshore area at Profile 27.

b. Profile 1 Area. - Except for about 200 feet adjacent to the river, the concrete sea-wall is fronted by a sand dune whose top is at the elevation of the top of the wall. The wall in the exposed

area is 4 to 5 feet above the beach. The backshore beach between the dune and the river end of the wall is soft sand. The foreshore beach is hard-packed sand. At about half-tide level, the foreshore beach becomes very flat. Southerly of the point, the high water line moves out from the wall to pass around the sand dune. The foreshore beach continues to be hard-packed sand. The backshore beach is fine soft sand with stone cusps occurring near the dune line.

c. Rice Avenue Area. - In the riprapped area at the southerly end of Rice Avenue, the beach is entirely hard-packed sand. There is no area of soft loose sand. This beach condition exists southerly to the Northern Circle sea-wall. Ripples are impressed in the sand at the low water line.

d. Profile 2. - Remains of a sand dune stand in front of retaining wall. The backshore is soft sand. The foreshore is hard-packed sand with stone cusps on the slope. Stones have piled up along the face of the remaining dune.

e. Stepped Sea-Wall. - The foreshore beach fronting the stepped sea-wall has a moderately steep slope to low water elevation and is of hard-packed sand, covered with small stones. Below low water elevation, the beach is mud. At the northerly end of the wall, the beach elevation is 1 to 1-1/2 feet below the bottom step. In the center section, the area where a row of wood piles stands in front of the wall, the beach elevation is 2-1/2 to 3 feet below the top of the bottom step. In this area, riprap shows above the sand about 10 feet in front of the wall. About 150 feet from the south end of the wall, the high water line moves seaward from the wall and the beach elevation rises to bury the bottom step.

f. Area South of Stepped Sea-Wall. - For a distance of about 150 feet, the backshore beach adjacent to the stepped sea-wall is sandy and is about 2-1/2 to 3 feet below the top of the highway curb wall. South of this, the backshore area is sandy for 15 to 20 feet adjacent to the high water line and then stony to the curb wall. The stone piles are cuspate in formation and are generally 6 to 12 inches below the top of the curb wall. The foreshore beach is hard sand with a definite gully running along the beach at the foot of the slope. This gully starts near Profile 4.

g. Profile 3 Area. - The backshore area is sandy, the sand apparently covering stone cusps. The foreshore beach is hard-packed sand with the slope ending in a stony gully at about half-tide elevation.

h. Oak Island Street Pavilion. - The beach elevation and slope in this area are about the same as in the previous winter except that the stones have been replaced with a fine, loose, white sand which contains no stone. The foreshore slope is hard-packed sand, with a gully about 18 inches deep occurring at about half-tide elevation. The gully contains a belt of stone.

i. Area Between Oak Island Street and Revere Street Pavilions. - The backshore beach is soft sand with scattered cusps of fine stone. There has been apparent erosion along the face of the highway curb wall where elevations are 2 feet below the top of the wall. The remaining sand bank fronting the wall appears to be 6 to 10 inches lower than at previous inspections. There is a deposit of pebbles at the foot of the bank. The foreshore beach is hard-packed sand with a gully occurring at about half-tide level. The gully is 6 to 10 inches deep.

j. Profile 5 Area. - The top three steps of the stepped sea-wall are bare of stones. Stones pile up the lower steps and onto the beach to almost high water line. The seaward edge of the stones

has a heavy cuspate form. There is soft sand between the valleys of the stone cusps. The foreshore beach is hard-packed sand with scattered small stones over the slope.

k. Profile 6 Area. - The stepped sea-wall is 70 to 80 per cent buried under stones which pile up to the level of the street. This deposit begins to thin out north of the bastion adjacent to Profile 6 until the north end of the wall is covered as described for Profile 5. The backshore beach is of soft sand, which at the bathhouse pavilion lies entirely back of the face of the pavilion wall. At the Revere Street Pavilion, the soft sand extends in front of the pavilion wall.

l. Profile 8 Area. - The beach fronting the pavilion is hard-packed sand. There are stone cusps on the beach at half-tide level. Stones cover the backshore area adjacent to both ends of the pavilion, but there are no stones in front of the pavilion.

m. Profile 10 Area. - The edge of the sidewalk is retained by a concrete curb wall. The backshore against the sidewalk curb is covered with stone 2 to 4 inches in average diameter. The stone piles up to the top of the curb wall. Just about high water, there is a belt of soft sand which is 3 to 4 feet wide. The foreshore beach is hard-packed sand.

n. Profile 12 Area. - The beach apparently has eroded, since the rubble foundation wall of the central bastion is exposed for 3 to 4 feet above the beach. The backshore area is generally soft sand with stones piled up against the base of the main pavilion walls. There are cusps of small stone on the backshore slope. The foreshore beach is hard-packed sand.

o. Profile 13 Area. - (1) The extreme backshore area is covered with stone and the area near high water elevation is covered with soft fine sand. Below high water elevation, the beach is of hard-packed sand.

(2) The beach south of Profile 13, toward Profile 16, is similar to that described above. This is the area from which a large stone beach ridge was removed in the spring for use as highway fill. The foreshore beach is of hard-packed sand. There is a line of shingle along the base of the slope. The backshore area adjacent to high water level is of soft sand. There is a pile of stone adjacent to the sidewalk which reaches the top of the walk.

p. Profile 16 Area. - (1) North of Profile 16, which is at Eliot Circle, the foreshore beach is hard-packed sand. South of the profile, the beach becomes a boulder-strewn beach. The beach ridge north of the circle has been removed for highway fill material, but a very short section still projects northerly from the wall. Fine sand is building up in back of this section of ridge.

(2) Between Profiles 16 and 17, the stone beach ridge remains in place. The beach is very stony.

q. Profile 17. - (1) The beach fronting the stone ridge, between Profiles 16 and 17, is covered with boulders for distances varying from 10 to 25 feet from the ridge. The foreshore is hard-packed sand. East of Profile 17, the beach fronting the wall and riprap, is composed of small stones, becoming boulder strewn about 50 feet seaward of the riprap.

(2) The beach on the west side of the groin, between Ranges 17 and 18, is slightly higher than on the east side. The beach on the east side of the groin, between Profiles 18 and 19, is about 2-1/2 feet higher than on the west side. The boulders covering the beach at Profile 17, extend easterly about 80 feet from the westerly groin where a sandy channel exten shoreward to the narrow backshore beach of fine stone and coarse sand. This fine stone and coarse sand beach extends between the two

groins and along their bases reaching a point about 20 feet from the outer end of the westerly groin and 35 feet from the end of the easterly groin. A wide belt of cobbles lies between the easterly edge of the sandy channel and the beach.

(3) The channel between the two groins appears to drain a pocket behind the riprap shore protection which is formed by the stone beach ridge extending from the granite block wall to a point east of the easterly groin. This ridge curves landward so that it is at one point about 50 feet landward of the riprap.

r. Profile 20. - On the north side of the jetty projecting from the Roughan's Point sea-wall toward Cherry Island Bar, the beach is very stony. On the south side of the jetty, the beach is a hard stony beach with some soft fine sand along the base of the ridge which covers the shore end of the jetty. At about half-tide, there is a shoal showing between the jetty and the Cherry Island breakwater.

3. Changes Due to Heavy Storms. - Changes in beach composition are effected by heavy storms and the extent of such is indicated by the following observations made on December 3, 1945 after the three-day northeast storm of November 28-30, 1945.

a. Heavy deposits of stones were laid over the sand dune between Profile 1 and a point midway between Profiles 1 and 2.

b. Between the Northern Circle sea-wall and a point 600 feet southeast of Profile 3, the backshore was covered with a heavy deposit of stone which assumed a cuspate formation and piled up against the retaining wall to street level.

c. In the area of Oak Island Street Pavilion, the beach was hard-packed sand containing small stone.

d. Between the Oak Island Street and Revere Street Pavilions, the beach level was lowered 6 to 12 inches and the backshore was covered with a very heavy deposit of stone.

e. Between Profiles 4 and 13, the stone deposit in backshore areas was only slightly greater than normally occurs in this area.

f. The stone ridge which extended from Profile 14 to 17 did not suffer any apparent change. The crest of this ridge was at the elevation of the Eliot Circle sea-wall and met the sea-wall at Profile 16. (This ridge had been in existence for some years but in the spring of 1946 was artificially removed northerly of Profile 16.)

APPENDIX III

COST ESTIMATE FOR REVERE BEACH

This estimate is made for the recommended project for the Metropolitan District Commission Reservation at Revere Beach between Northern Circle and Profile 13.

I. FIRST COSTS

Placement of sand fill and removal of stone deposits which will be less than 3 feet below top of fill or are on stepped sea wall.

Removing Stone Deposits	$1,300
Sand Fill, 522,000 cubic yards at $1.85	965,700
	$967,000
Engineering and Contingencies	145,000
	$1,012,000

II. ANNUAL CARRYING CHARGES

1. Allocation of Costs.

The plan of improvement between Northern Circle to Profile 13 qualifies under the provisions of Public Law 727 for Federal participation to the extent of one-third of the total first cost of the project. First costs are therefor allocated as follows:

Federal Cost	$337,300
Non-Federal Cost	674,700
Total Cost	$1,012,000

2. Federal Annual Carrying Charge.

a.	Interest - 3% of $337,300	$10,120
b.	Amortization of depreciation and obsolescence, estimated period 40 years ($337,300)(.01326)	4,470
c.	Maintenance	0
d.	Total Federal Carrying Charge	$14,590

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3. Non-Federal Annual Carrying Charge.

a.	Interest 3-1/2 % of $674,700	$23,610
b.	Amortization - 40 year Period ($674,700)(.01183)	7,980
c.	Estimated Annual Maintenance*	10,630
d.	Total Non-Federal Carrying Charge	$42,220

*Determination of Annual Maintenance.

The average annual volumetric changes between the sidewalk line and the position of mean low water in 1900 for the area between Profiles 2 and 12, which is comparable to the area to be sanded, are given in Table D in Paragraph 38 of the report. The average annual change for the longest period of record, 1900 to 1946, is a loss of 3700 cubic yards per year. Computations for changes between Profiles 4 - 12, distance 4000 feet, are based upon more detailed surveys than those for changes between Profiles 2 - 4, distance 7500 feet. Assuming the rate of erosion over the entire beach was the same as between Profiles 4 - 12, the change would have been a loss of $\frac{11500}{4000} \times 1242 = 3571$ cubic yards, a loss which is approximately that computed directly for the entire beach. The length of beach to be sanded is 12900 feet long, Northern Circle to Profile 13. Applying the above ratio of erosion of 3700 cubic yards per year to this length of beach, the annual loss will be $\frac{12900}{11500} \times 3700 = 4100$ cubic yards per year. In order to provide a degree of conservatism in estimating a rate of future erosion, a quantity of 5000 cubic yards per year has been used. This rate is 22 percent greater than the actual experience rate computed above.

5000 cubic yards at $1.85	$9,250
Engineering and Contingencies	1,380
	$10,630

4. Total Annual Carrying Charge. $56,810

R

APPENDIX IV

ANNUAL BENEFITS FOR REVERE BEACH

(Northern Circle to Eliot Circle)

1. Average Annual Direct Damage Prevented. -

a. Federal		$ 0
b. Non-Federal Public		
(1)#	M.D.C. Expenditures	6,000
(2)*	Annual charges for required major repairs	3,900
(3)	Present annual average loss of beach materials - 3700 cubic yards at $1.85	6,845
c. Private		0
	Total	$16,745

#Exclusive of major repairs of deteriorated structures.
*The estimated cost of repairing the most severely deteriorated sea-walls is $83,000. This work will be unnecessary if the recommended project is accomplished. Annual charges for this work, computed at 3.5 percent interest and amortized over a 40-year period, is $83,000 x (.035 + .01183) = $3900. This item includes armoring the exposed surface of the pavilion at Profile 12 and the sea-wall between Profiles 4 and 7 with gunite, rebuilding the lower steps of the seawall near Profile 2 and repair of other walls.

2. Increased Property Values Resulting from Shore Protection. - Property adjacent to Revere Beach Drive will increase in value as the result of the greater degree of protection afforded by the proposed work. Since public property will be retained in public ownership, no benefit is evaluated for such property. Private property is subject to resale and benefit due to increased value may be realized through resale of the

property. This increase will be larger in the area between Northern Circle and Revere Street, where present protective structures are inadequate and in danger of being undermined, than between Revere Street and Eliot Circle where the present structures are more nearly adequate. It is estimated that the proposed work will result in a 10 percent increase in property values due to shore protection in the area north of Revere Street and 5 percent in the area south of Revere Street. Benefits resulting from this increase in value are as follows:

a. Federal $ 0

b. Non-Federal Public

(1) Northern Circle to Revere Street.
Assessed Value of Frontal Property - $856,200.
Tax Rate, $51.80 per $1,000.
Increased Tax Return $856,000 x .10 x .0518 = 4,430

(2) Revere Street to Profile 13.
Length of improvement 4500 feet. Assessed Value of Frontal Property between Revere Street to Profile 17 - $2,132,600.
Length 6500 feet
Increased Tax Return $2,132,600 x $\frac{4500}{6500}$ x .05 x .0518 = 3,820

(3) Total Non-Federal Public Benefit= $8,250

c. Private

Increased value of private frontal property will not be realized unless property is resold. The net capital gain after deduction of taxes and other expenses can be measured by the interest on the gain at 3.5 percent.

(1) Northern Circle to Revere Street

$856,000 x .10 x .35 = $3,000

(2) Revere Street to Profile 13

$2,132,600 x $\frac{4500}{6500}$ x .05 x .035 = 2,580

(3) Total Private Gain = $5,580

d. Total benefit $13,830

3. Recreational Benefits. - The proposed plan will eliminate an objectional stony beach condition and double the area of dry beach above mean high water. This area will be used to accomodate additional patrons and to alleviate crowded conditions on existing dry beach. This project results in great recreational benefits, particularly in view of the established desirability of the area for recreational purposes.

a. Federal. - Federal interests are not involved.

Federal Benefit = 0

b. Non-Federal Public . - (1) While the State of Massachusetts does not make a charge for the use of the beach, the benefit to the public may be evaluated in the terms of increased fees which it would pay were the beach privately owned and operated. It is conservatively estimated that the daily attendance will be increased 20 percent by the improvement of the beach. The daily attendance is reported to be

150,000 to 200,000 persons per day. Assuming one-third of these people are attracted solely by the amusement park, the minimum daily beach attendance will be 100,000. During the summer season of 10 weeks, allowing 25 percent for inclement weather, the minimum annual attendance is 100,000 x (10 x 7) x .75 = 5,250,000 people. The increased attendance due to beach improvement will be 5,250,000 x .20 = 1,050,000 people. The lowest charge generally made for the use of a beach is 10 cents per person. It is considered that the public would be willing to pay a minimum of 10 percent more on such a charge for the use of a sandy beach. On this basis the benefits derived by each patron currently using the beach is one-tenth of 10 cents, or one cent, and the benefit derived by each new patron is the total value to current patrons or 11 cents. The minimum evaluation of the total benefit realized by the public from the improved beach in terms of annual attendance becomes:

5,250,000 x $.01 = $52,500

1,050,000 x $.11 = 115,500

$168,000

(2) Private property will increase in value as the result of the improved recreational facilities. The increased valuations are discussed in subparagraph c. below being 3 percent between Northern Circle and Revere Street and 13 percent between Revere Street and Profile 17. The Non-Federal public will derive a benefit from the increased valuation through increased tax returns thereon. The increased tax returns will be as follows:

Northern Circle to Revere Street	
All property, $885,700 x .03 x	
.0518 =	$ 1,380
Revere Street to Profile 17	
Frontal Property, $2,132,600 x	
.13 x .0518 =	14,360
Marginal Property, $544,900 x .75 x	
.13 x .0518 =	2,750
Total Tax Return	$ 18,490

(3) Total Non-Federal Public Benefit = $186,490

c. Private. - (1) Northern Circle to Revere Street. - Recreational benefits to be derived by private property comprise increased earning power derived from the proximity to the improved beach. Property lying east of the Narrow Gauge Railroad between Northern Circle and Revere Street will experience increased earning power through the increased volume of business in restaurants and refreshment stands due to increased beach patronage, and through the actual or possible increased rentals of residential properties due to the improved beach. Summer beach patronage, it is estimated, will increase 20 percent which increase is equal to 13 percent of the total patronage of the beach and amusement area, and hence business possibilities will increase 13 percent during the summer season. The area considered is not entirely devoted to summer enterprises, and the increase must be considered on an annual basis, under which conditions the increase is 3 percent of the annual volume of business. This gain may be evaluated in terms of increased rentals of properties, actual or possible, for business and residential purposes. Assuming the annual rental to be 12 percent of

the assessed valuation, the gross gain is

$885,700 x .12 x .03 = $ 3,190

Deducting taxes of $1,380 as computed in Paragraph 3-b-(2) above, the net gain is $1,810.

(2) Revere Street to Profile 17. - Private property south of Revere Street to Profile 17 fronting the beach is used almost entirely for summer amusement enterprises. Marginal property between the frontal property and the Narrow Gauge Railroad is developed for amusement purposes to such a degree that it is considered that 75 percent of its value is due to summer business possibilities. All property in this area will experience an increase in value due to the increase in beach patronage derived from the improvement of the beach. The increase in values will be in direct ratio with the increased patronage which is estimated to be 13 percent. This gain may be evaluated in terms of increased returns on property investments through increased rentals. On the basis that frontal property rental income is entirely derived from summer business possibilities, marginal property rental income is 75 percent due to summer business possibilities, and that average rentals are 12 percent of assessed valuations, the gross gain is as follows:

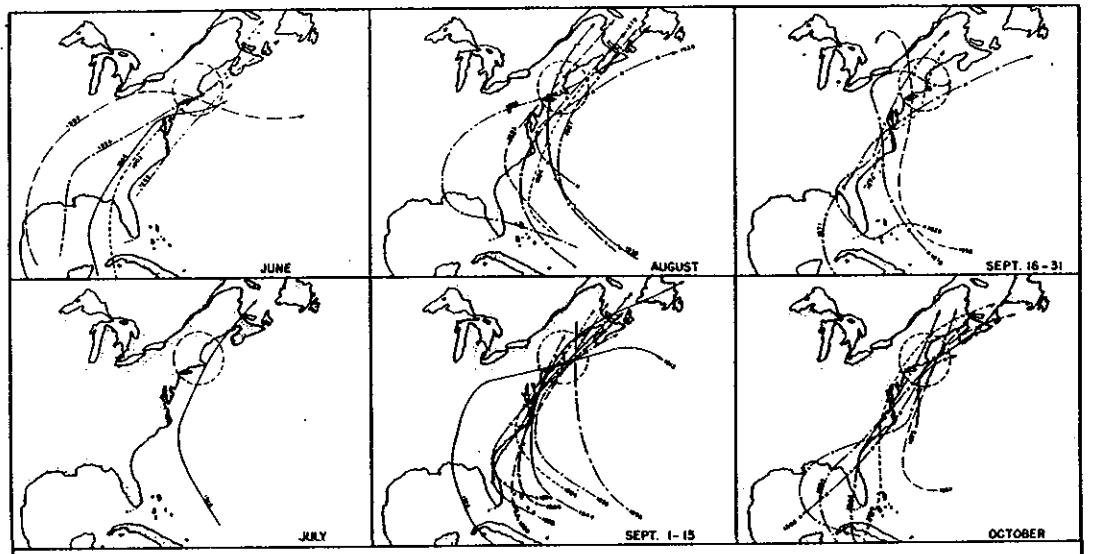
Frontal Property	
$2,132,600 x .12 x .13 =	$33,270
Marginal Property	
($44,900 x .75) x .12 x .13 =	6,380
Total Gross Gain	$39,650
Less Taxes (Par. b.)	17,110
Net Private Gain =	$22,540
(3) Total Private Benefits	$24,350

R

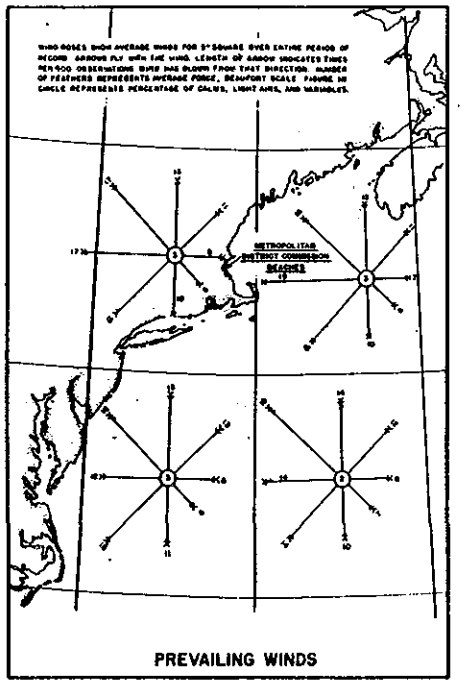
d. Total Recreational Benefits $210,840

(4) Total Benefits. - The total benefits evaluated herein are as follows:

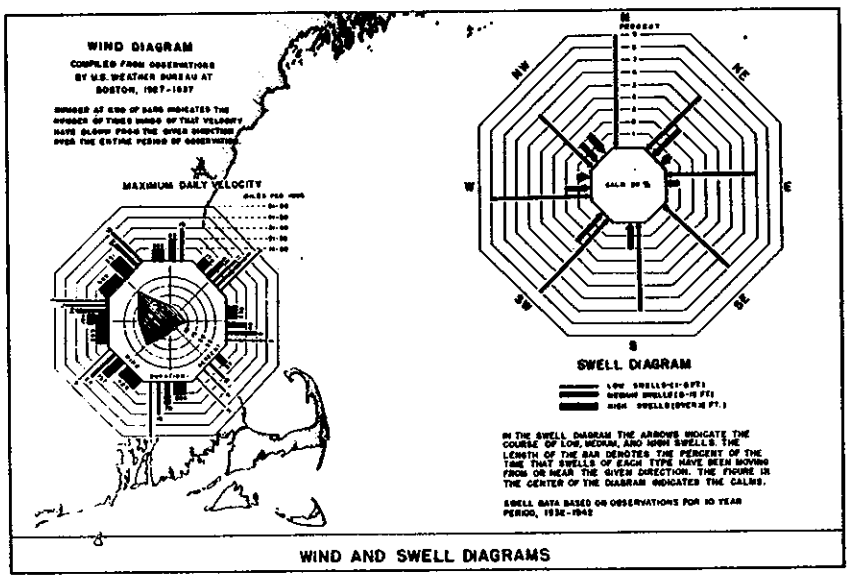
	Federal	Non-Federal Public	Private	Total
Direct Damages Prevented	$ 0	$ 16,745	$ 0	$ 16,745
Increased Valuation from Shore Protection	0	8,250	5,580	13,830
Recreational Benefits	0	186,490	24,350	210,840
Totals	$ 0	$211,485	$29,930	$241,415



PATHS OF TROPICAL STORMS OF HURRICANE INTENSITY



PREVAILING WINDS



WIND AND SWELL DIAGRAMS

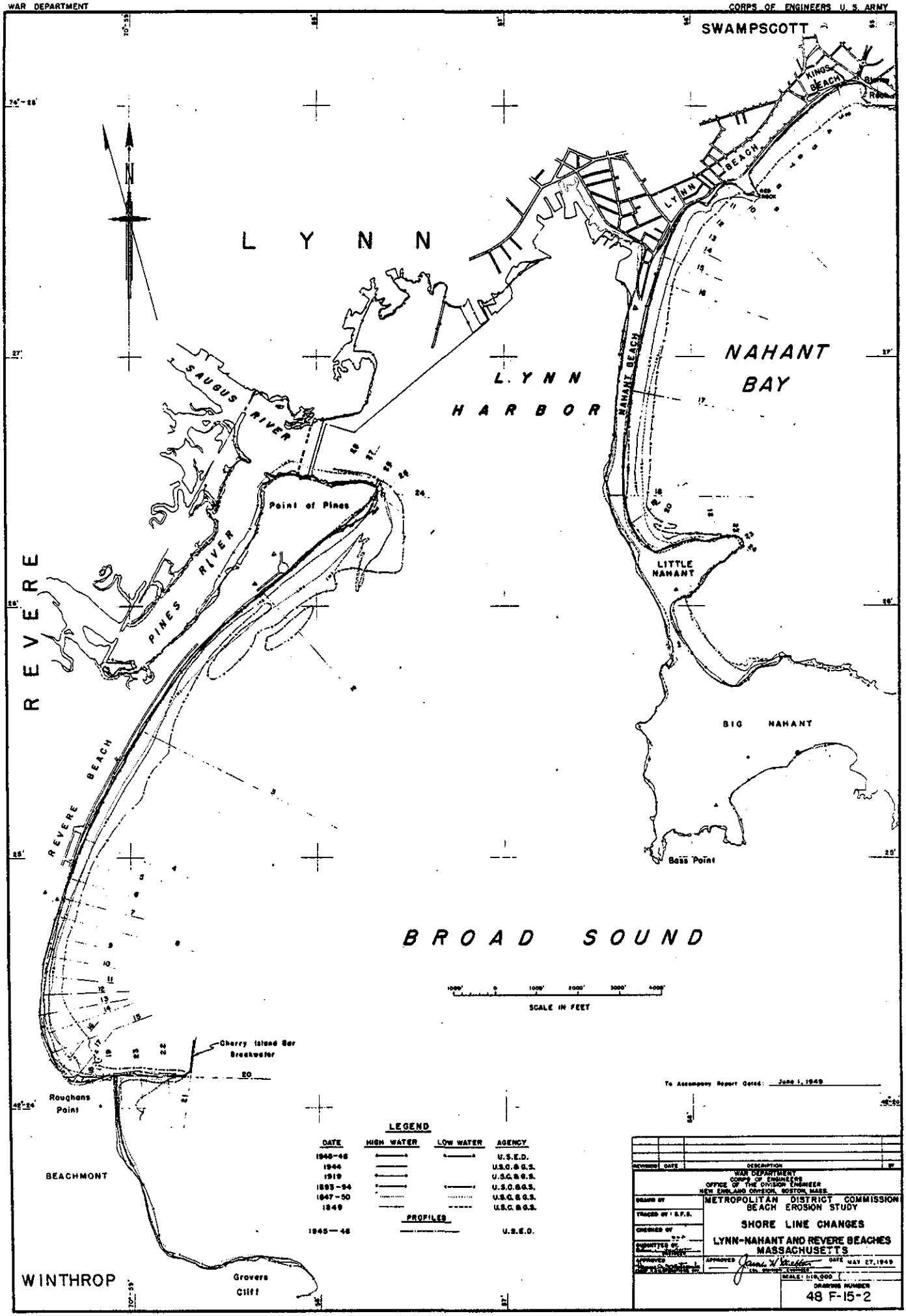
To Accompany Report Dated: June 1, 1948

	WAR DEPARTMENT CORPS OF ENGINEERS OFFICE OF THE DIVISION ENGINEER NEW ENGLAND DIVISION, BOSTON, MASS.
DRAWN BY	METROPOLITAN DISTRICT COMMISSION
TRACED BY R.S.B.	BEACH EROSION STUDY
CHECKED BY	WIND AND SWELL DIAGRAMS
SUBMITTED BY	HURRICANES AND PREVAILING WINDS
APPROVED:	APPROVED DATE MAY 27, 1948
	SCALE AS SHOWN
	DRAWING NUMBER 46-F-15-2

PLATE 2

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY



LEGEND

DATE	HIGH WATER	LOW WATER	AGENCY
1946-48			U.S.E.D.
1944			U.S.C.&G.S.
1919			U.S.C.&G.S.
1893-94			U.S.C.&G.S.
1847-50			U.S.C.&G.S.
1849			U.S.C.&G.S.

PROFILES

1945-48		U.S.E.D.

To Accompany Report Dated: June 1, 1949

REVISIONS	DATE	DESCRIPTION	BY

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

DRAWN BY
TRACED BY I. S. P. D.
CHECKED BY
SUBMITTED BY
APPROVED

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY

SHORE LINE CHANGES

LYNN-NAHANT AND REVERE BEACHES
MASSACHUSETTS

APPROVED James K. Vardaman, Jr. Col. Corps of Engineers
DATE MAY 27, 1949

SCALE: 1:10,000

DRAWING NUMBER
48 F-15-2

PLATE A-2

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY

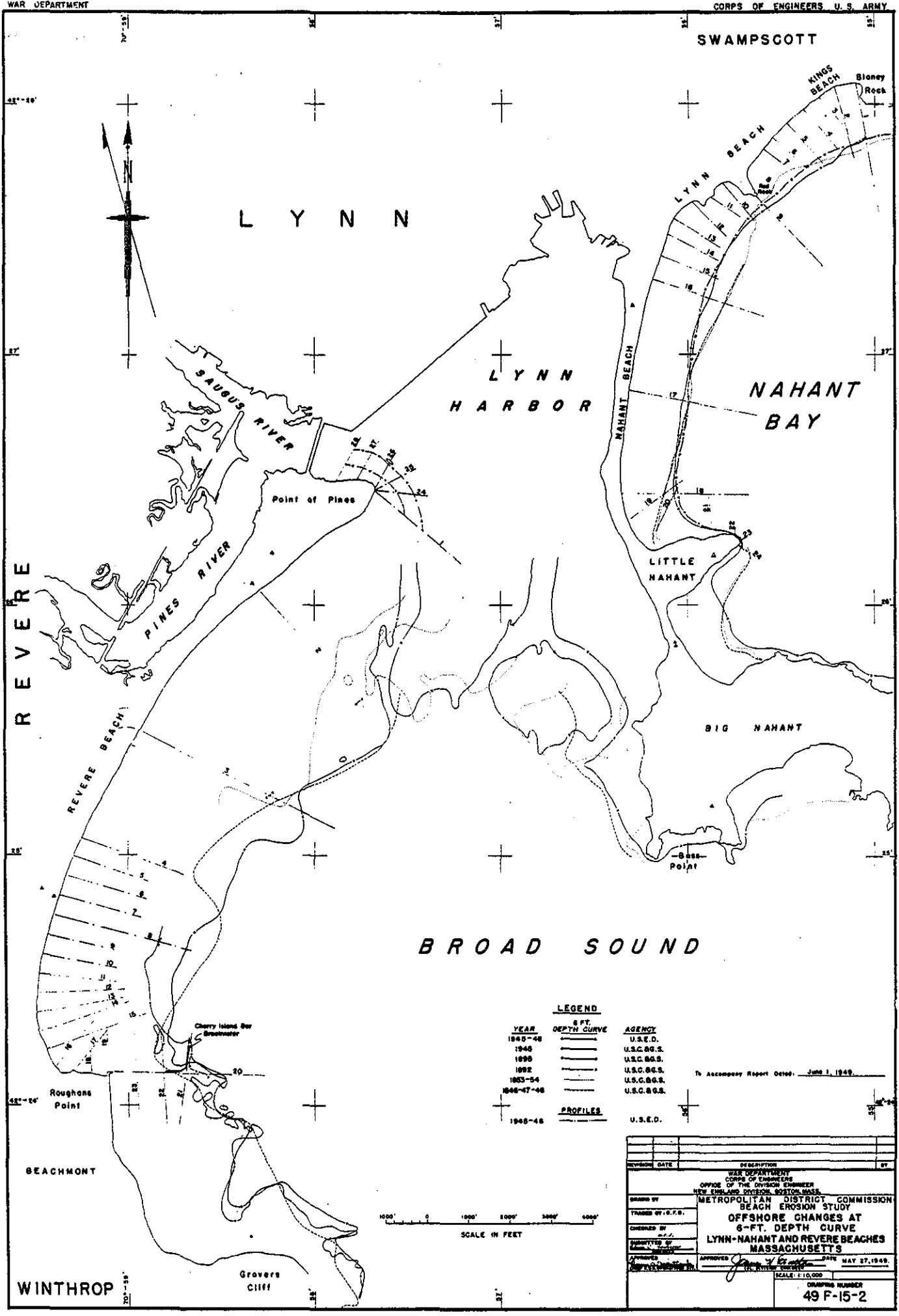
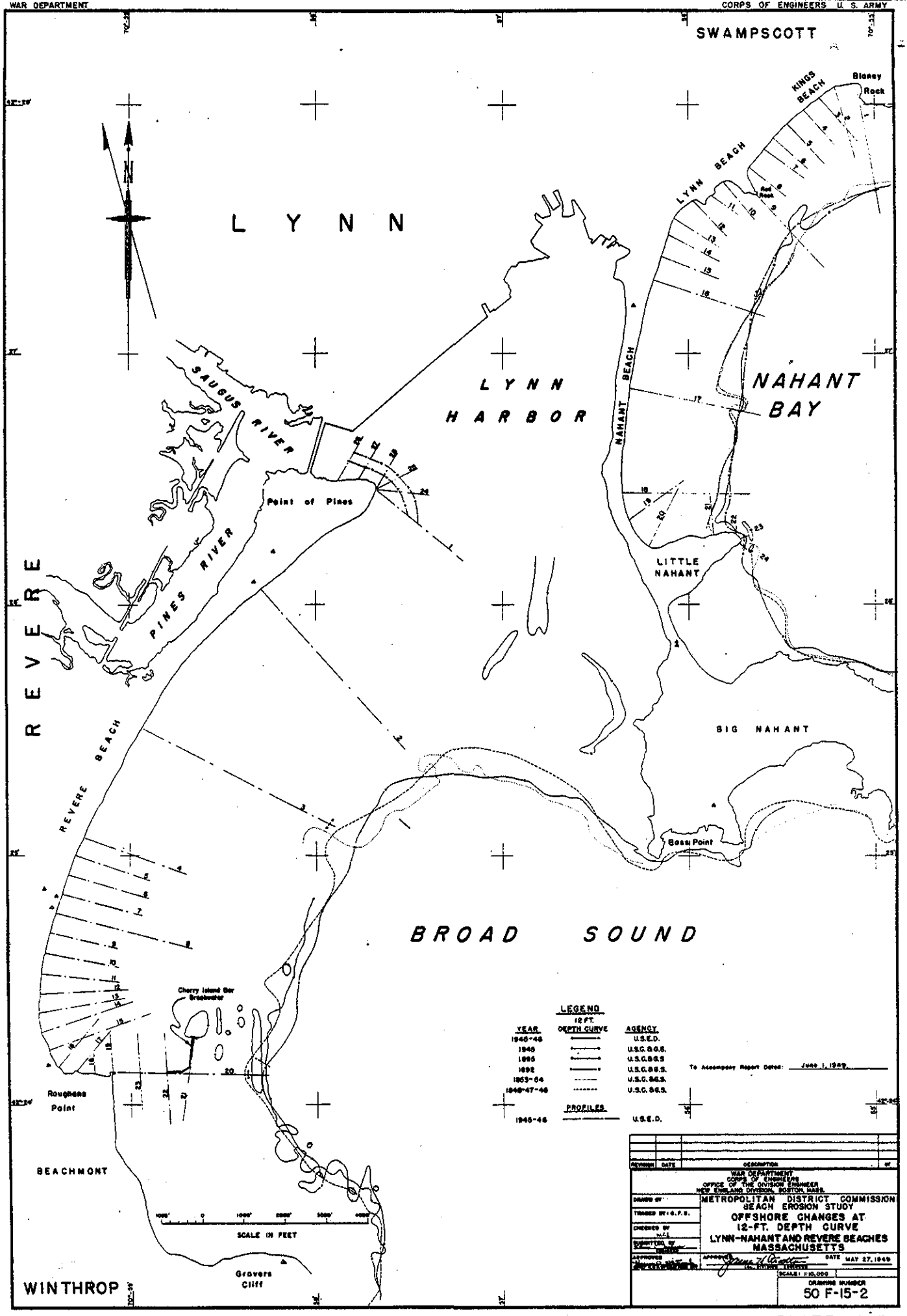


PLATE A-3



REVISED	DATE	DESCRIPTION	BY

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

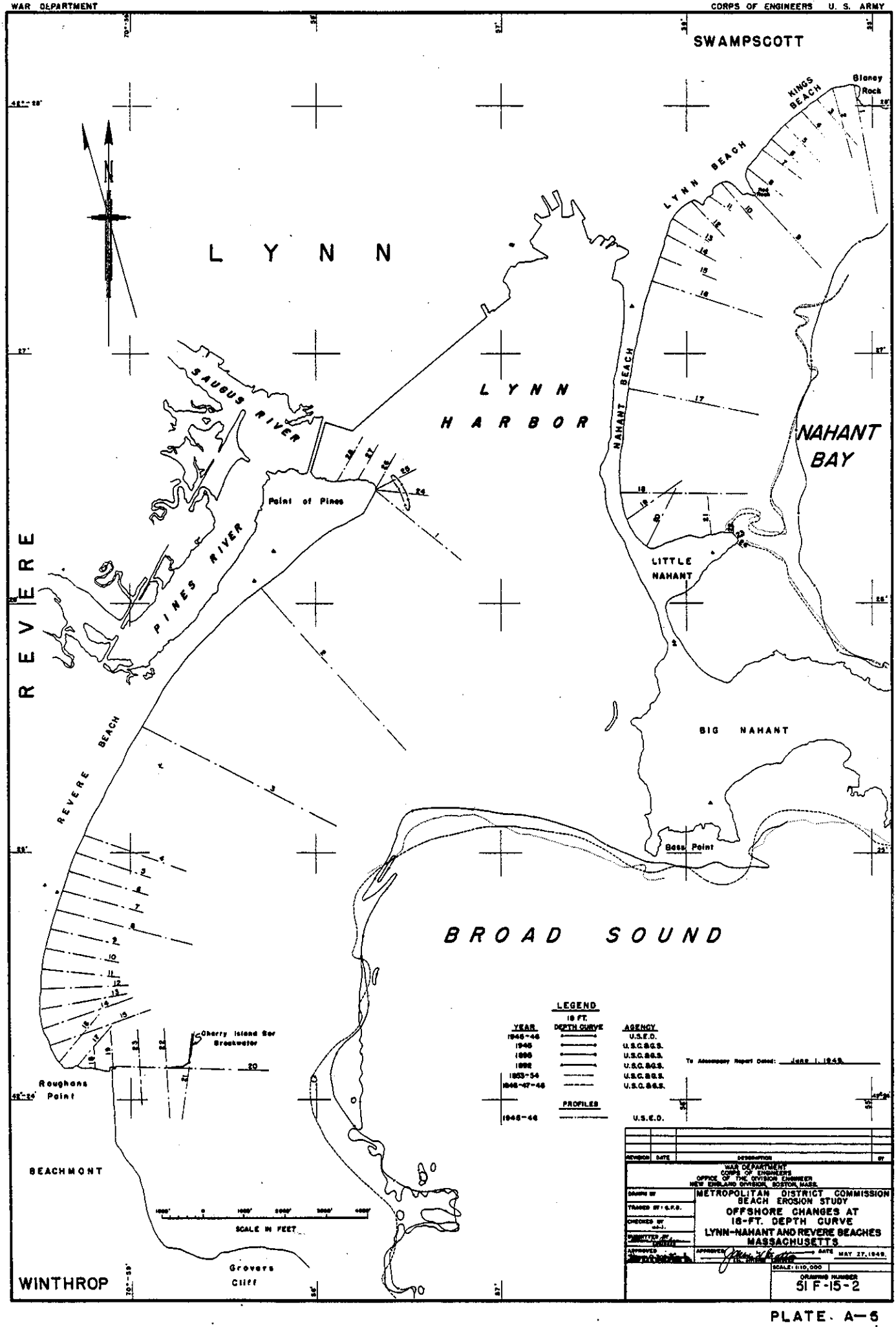
DRAWN BY
TRACED BY: H.F.S.
CHECKED BY
SUBMITTED BY
APPROVED

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY
OFFSHORE CHANGES AT
12-FT. DEPTH CURVE
LYNN-NAHANT AND REVERE BEACHES
MASSACHUSETTS

APPROVED DATE MAY 27, 1949
SCALE: 1:10,000
DRAWING NUMBER
50 F-15-2

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY



REVISION	DATE	DESCRIPTION	BY

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

DRAWN BY

TRACED BY: U.S.E.D.

CHECKED BY (Mod.)

SUBMITTED BY (Mod.)

APPROVED

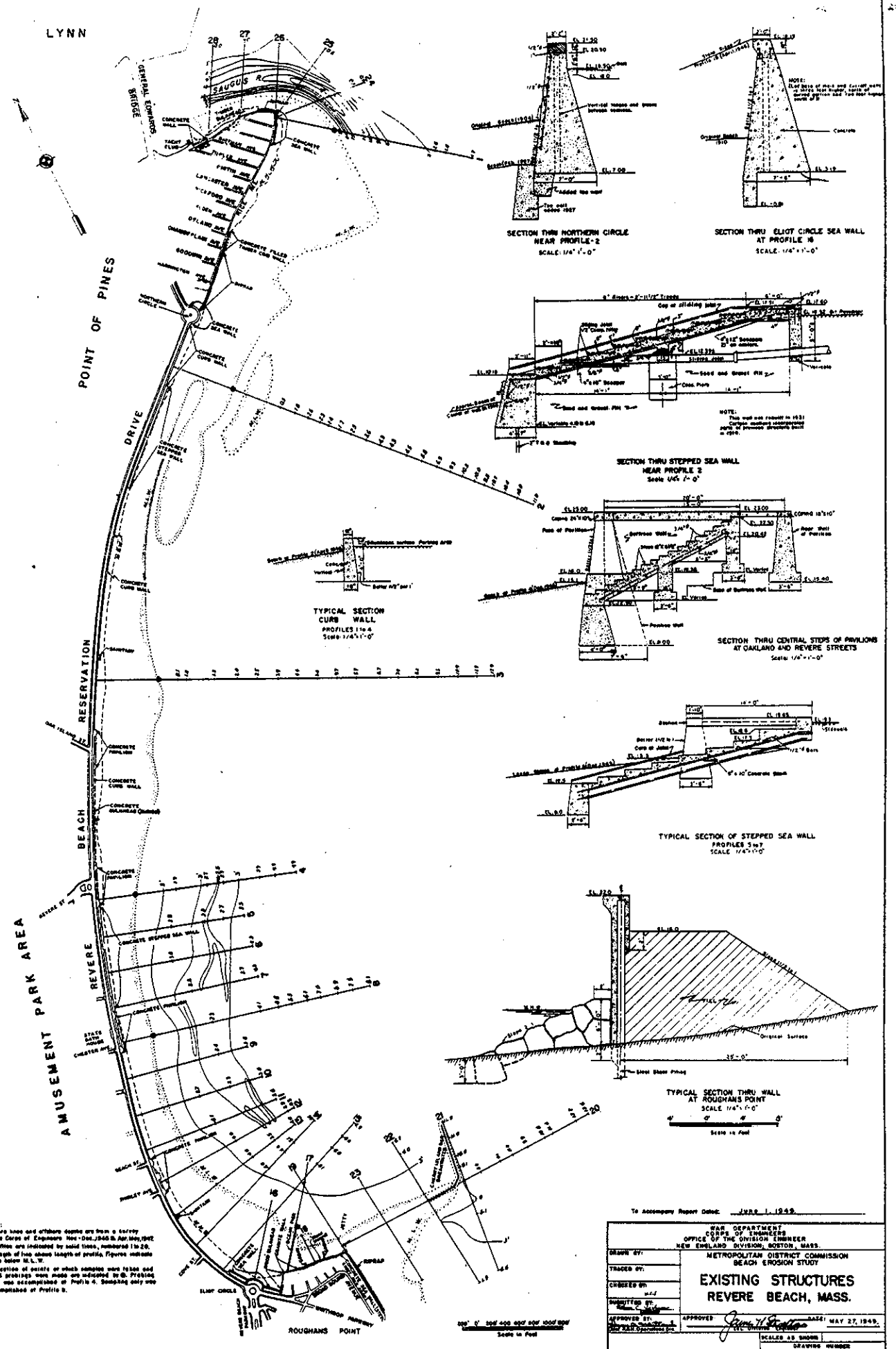
APPROVED DATE MAY 27, 1949.

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY
OFFSHORE CHANGES AT
18-FT. DEPTH CURVE
LYNN-NAHANT AND REVERE BEACHES
MASSACHUSETTS

SCALE: 1:10,000

DRAWING NUMBER
51 F-15-2

PLATE A-5



NOTE:
Shore lines and offshore depths are from a survey by the Corps of Engineers Nov - Dec. 1940 & Apr. May, 1941
Profiles are indicated by solid lines, numbered 1 to 20.
Length of line above length of profile, figures indicate depth below M.L.W.
Location of points at which samples were taken and hand probings were made are indicated by ⊕. Probing only was accomplished at Profile 4. Sampling only was accomplished at Profile 8.

To Accompany Report Dated: June 1, 1949.

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY

EXISTING STRUCTURES
REVERE BEACH, MASS.

DRAWN BY:	
TRACED BY:	
CHECKED BY:	
SUBMITTED BY:	
APPROVED BY:	APPROVED: DATE: MAY 27, 1949.

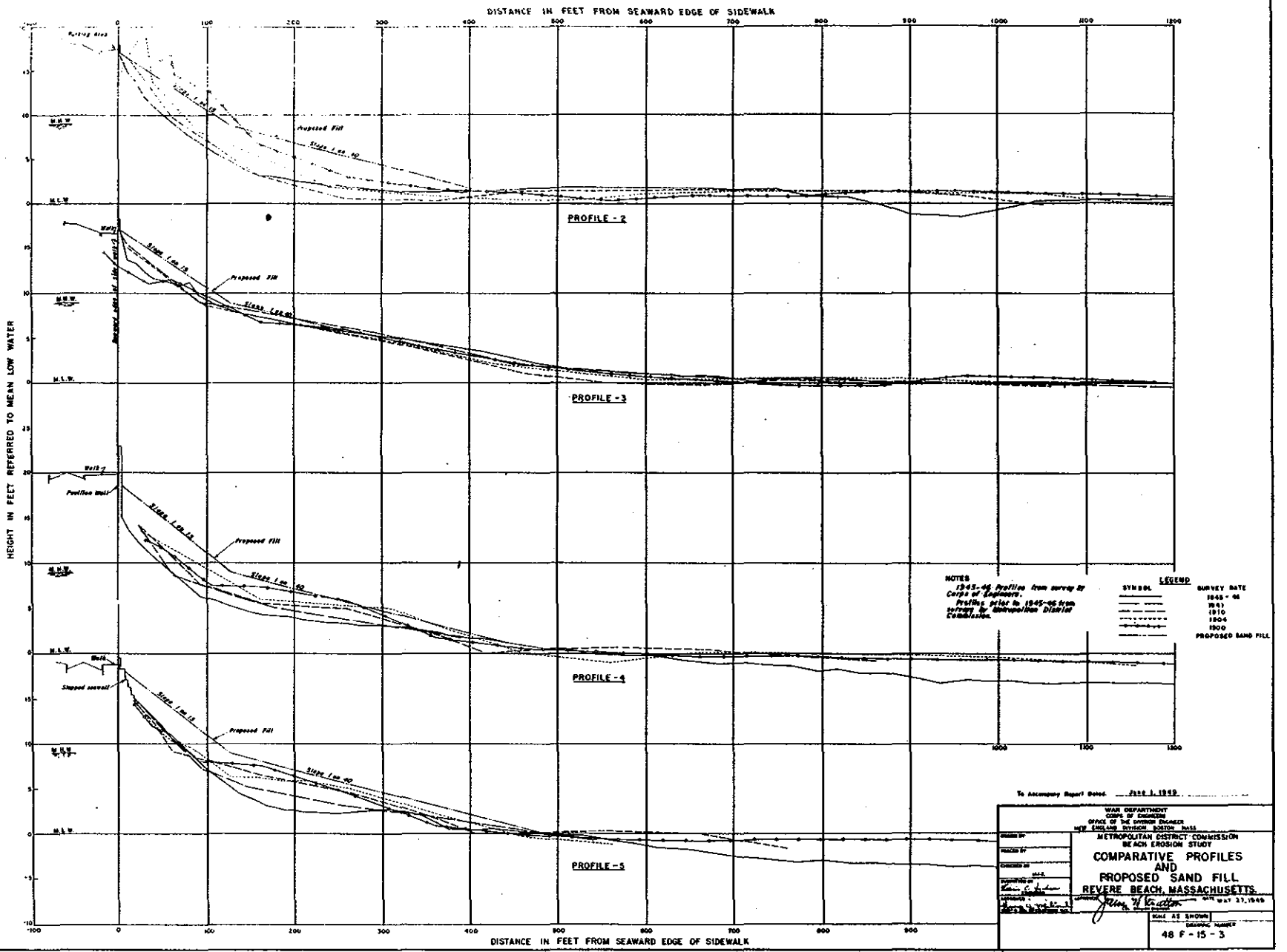
SCALES AS SHOWN

DRAWING NUMBER
47 F-15-3

PLATE-B-1

WAR DEPARTMENT

CORPS OF ENGINEERS



To Accompany Report Dated June 1, 1949

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY

COMPARATIVE PROFILES AND PROPOSED SAND FILL REVERE BEACH, MASSACHUSETTS

DRAWN BY
TRACED BY
CHECKED BY
SUBMITTED
RECOMMENDED
APPROVED

DATE MAY 27, 1949

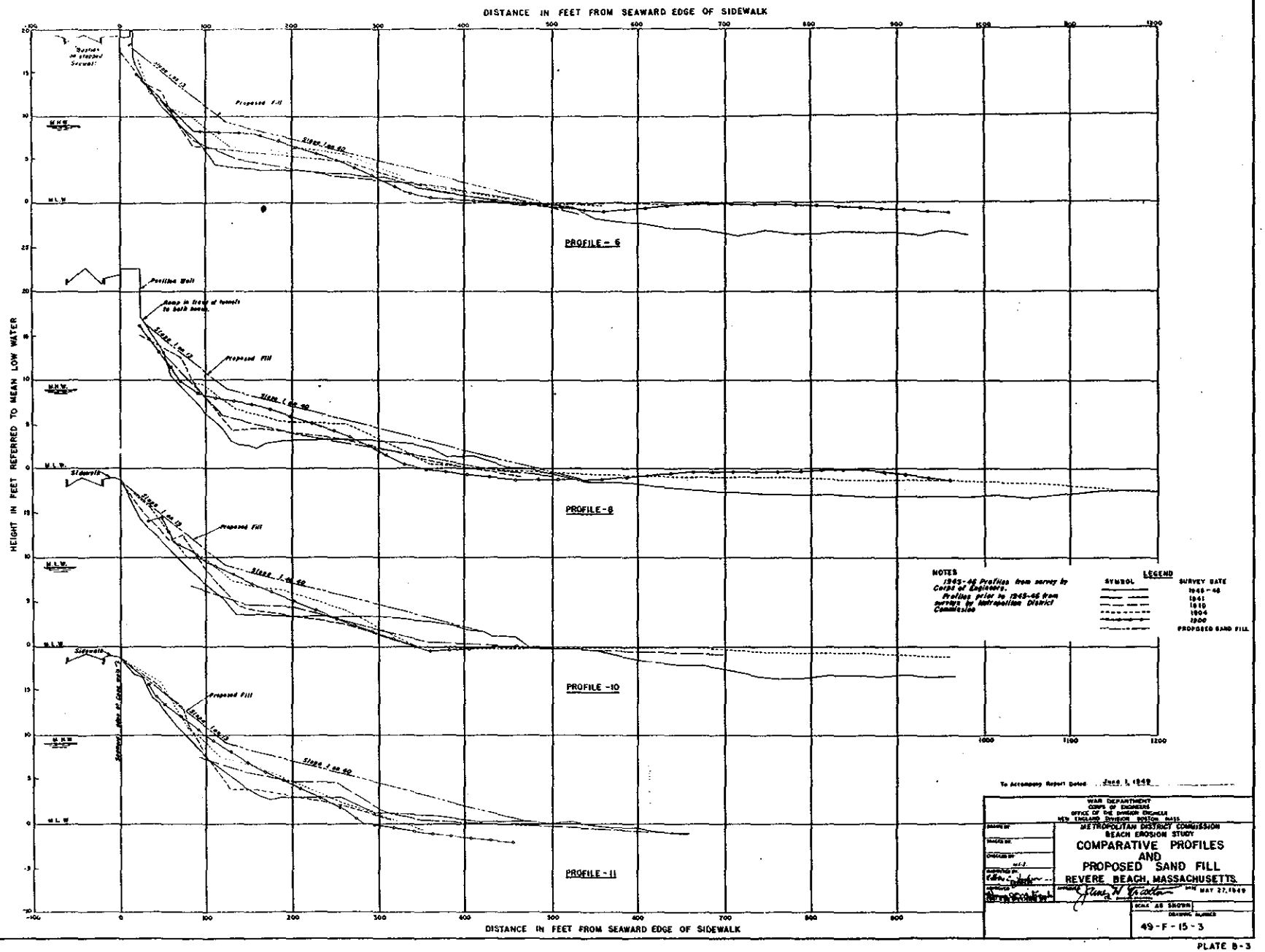
SCALE AS SHOWN

DRAWING NUMBER
48 F - 15 - 3

PLATE B-2

WAR DEPARTMENT

CORPS OF ENGINEERS



To Accompany Report Dated June 1, 1949

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY

COMPARATIVE PROFILES AND PROPOSED SAND FILL REVERE BEACH, MASSACHUSETTS

DATE MAY 27, 1949

SCALE AS SHOWN

DRAWING NUMBER
49 - F - 15 - 3

PLATE B-3

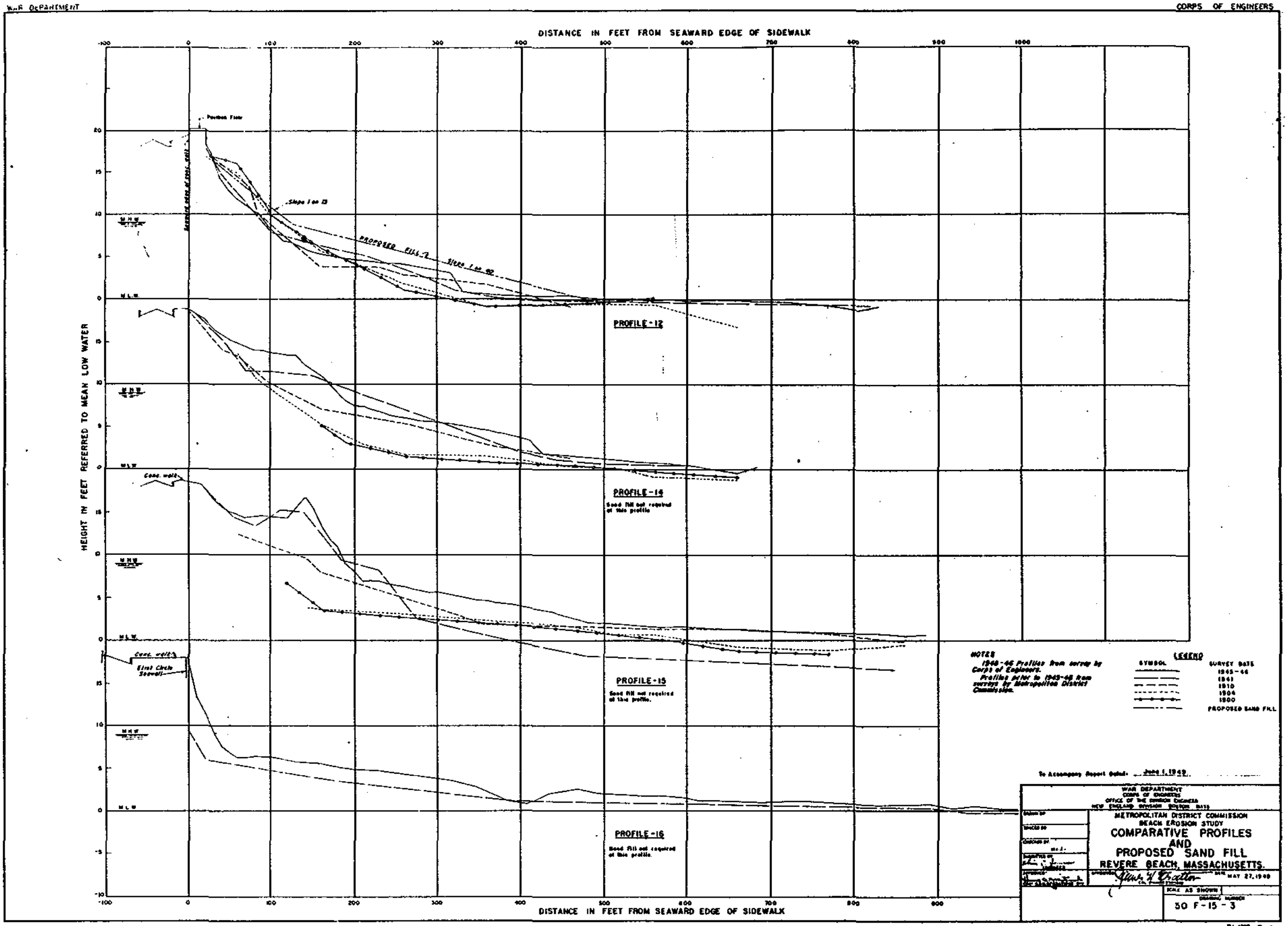

WAR DEPARTMENT
CORPS OF ENGINEERS
DISTANCE IN FEET FROM SEAWARD EDGE OF SIDEWALK
HEIGHT IN FEET REFERRED TO MEAN LOW WATER
M.H.W.
M.L.W.
Slope 1 on 13
PROPOSED FILL
PROFILE - 12
PROFILE - 14
Sand fill not required at this profile.
Conc. wall
PROFILE - 15
Sand fill not required at this profile.
Elliot Circle Seawall
PROFILE - 16
Sand fill not required at this profile.
NOTES
1945-46 Profiles from survey by Corps of Engineers.
Profiles prior to 1945-46 from surveys by Metropolitan District Commission.
LEGEND
SYMBOL
SURVEY DATE
1945-46
1941
1910
1904
1900
PROPOSED SAND FILL
To Accompany Report Dated: June 1, 1949
WAR DEPARTMENT
CORPS OF ENGINEERS
METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY
COMPARATIVE PROFILES
AND
PROPOSED SAND FILL
REVERE BEACH, MASSACHUSETTS.
MAY 27, 1949
SCALE AS SHOWN
50 F-15-3

PLATE B-4

Looking northeast along Point of Pines from foot of Harrington St. (About 1200 feet north of Profile 2)

Looking northeast along stepped seawall south of Profile 2. Note erosion in center of wall and damage to wall.

Metropolitan District Commission Study
BEACH CONDITIONS
REVERE BEACH, MASS.
Fig. B-1